JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 39 April, 1946 No. 2

CONTENTS

Sulfathiazole as a Medication for American Foul Brood Disease of Honeybees ..... J. PETER JOHNSON AND ROY STADEL 141

Effect of Calcic and Magnesic Diluents of Calcium Arsenate on Bean Yields .... JOHN H. HAWKINS 145

Diatomaceous Diluents for Dusts ..... NEELY TURNER 149

Cat-Facing and Dimpling in Peaches ..... A. M. WOODSIDE 158

Life History Studies of *Euschistus servus* and *E. tristigmus* .. A. M. WOODSIDE 161

Life History and Habits of *Strigoderma arboricola* ..... J. M. GRAYSON 163

The European Chafer *Amphimallon majalis* and Its Control in Lawns ..... F. L. GAMBRELL 168

Chemical Methods for Analysis of Dichloro-diphenyl-trichloroethane (DDT) .. J. M. GINSBURG 174

The Mode of Toxic Action of Dinitro Compounds on the Honeybee ..... G. J. GOBLE AND R. L. PATTON 177

DDT on Peaches: Three Years Field Experiments ..... BYRLEY F. DRIGGERS 181

DDT and Other New Insecticides for Control of Cauliflower Worms on Long Island ..... H. C. HUCKETT 184

Control of Aphids on Potatoes in Northeastern Maine ..... T. F. BRONSON AND FLOYD F. SMITH 189

DDT as a Control for the Pea Aphid ..... HUGH GLASGOW 195

Insecticidal Aerosols for Pea Aphid Control—Second Report ..... L. P. DITMAN, LYLE D. GOODHUE, FLOYD F. SMITH AND GEO. BURKHARDT 199

DDT to Control Potato Aphids ..... G. G. GYRISKO, GEORGE P. WENE AND W. A. RAWLINS 205

DDT for Codling Moth Control in Western New York in 1945 .. S. W. HARMAN 208

DDT and *Ryanex* to Control Oriental Fruit Moth: Their Effect upon Parasite Populations ..... E. H. WHEELER AND A. A. LA PLANTE, JR. 211

New Formulations of Aerosols Dispersed by Liquefied Gases ..... E. R. MCGOVRAN, J. H. FALES AND L. D. GOODHUE 216

DDT Preparations for Control of the Pea Aphid ..... L. P. DITMAN 219

Particle-Size Distribution in Liquefied-Gas Aerosols ..... LYLE D. GOODHUE AND R. L. RILEY 223

The Thermal Aerosol Fog Generator for Large Scale Application of DDT and Other Insecticides ..... R. D. GLASGOW AND D. L. COLLINS 227

Control of the American Dog Tick, a Vector of Rocky Mountain Spotted Fever: Preliminary Tests.....R. D. Glasgow and D. L. Collins 235

DDT Thermal Aerosol Fogs to Control Clothes Moths in a Wool Storage Warehouse.....D. L. Collins and R. D. Glasgow 241

Japanese Beetle Attractants with Special Reference to Caproic Acid and Phenyl Ethyl Butyrate.....George S. Langford and Ernest N. Cory 245

Rate of Development of Milky Disease in Japanese Beetle Populations.....J. A. Adams and E. H. Wheeler 248

An Evaluation of Various Sprays to Control Immature Squash Bugs.....Thomas C. Watkins 255

Scientific Notes

Some New Insecticides for Potato Insect Control.....George G. Gyrisko 262

Eradication of Boxwood Leafminer and Boxwood Psyllid.....Louis Pyenson 264

Effect of Various Dust Mixtures on Incidence of Cabbage Aphid.....G. E. R. Hervey 265

The Control of Mites on Apple Trees Sprayed with DDT.....W. S. Hough 266

Compatibility of DDT and Fungicides on Potatoes..J. W. Heuberger and L. A. Stearns 267

The Control of the Cowpea Curculio.....L. A. Hetrick 268

Individual Comparisons of Grouped Data by Ranking Methods.....Frank Wilcoxon 269

Two Industry Problems Caused by Release of DDT.....Charles L. Smith 270

DDT and Lead Arsenate Compared for Control of the Pecan Nut Casebearer: 1945 Tests.....C. B. Nickels 272

Sabadilla and DDT to Control the Squash Bug.....R. R. Walton 273

DDT for Control of a Booklouse.....D. D. Jensen and F. G. Holdaway 274

Hadrobregmus gibbicollis Infesting Woodwork.....Melville W. Hatch 274

An Early Use of Arsenic as an Insecticide.....J. A. Munro 274

Editorial..... 275

Proceedings, Seventeenth Annual Meeting of the Eastern Branch..... 278

JOURNAL OF ECONOMIC ENTOMOLOGY

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Sulfathiazole as a Medication for American Foul Brood Disease of Honeybees

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It is stated in the annual reports (Zappe 1941–1945) of the State Entomologist of Connecticut, under Inspection of Apiaries, that a total of 60,312 colonies of bees were inspected during the five-year period 1940 to 1944 inclusive, and that 2034 colonies, or 3.37 per cent, were found infected with American foul brood and destroyed. As complete working colonies have been conservatively valued at $20.00 each during the last few years, it follows that the disease has been responsible for an annual average loss of $8,136.00, which totals $40,680.00 for the 5-year period.

When viewed alone, the losses in Connecticut, which ranks approximately forty-first among the states in honey production, do not appear to be excessive. However, when viewed from a national standpoint, the annual losses due to this disease become of great economic importance. Dadant (1937), in 1937, reported that the annual losses easily approach $2,000,000.00. As the incidence of disease has not materially changed since then, and if present-day costs were considered, the annual losses to the beekeepers would easily double Dadant's estimate.

Haseman & Childers (1944), of Missouri, reported on the control of American foul brood with sulfathiazole. Their work is considered of great importance, as it was the first time positive evidence of success was obtained in attempting to control the disease in active colonies by chemical treatment. It also indicated that there was a possibility of eliminating the disease in apiaries if the material was used properly.

Sulfathiazole is one of the newer chemicals now widely used as a drug by doctors, dentists and veterinarians. It is bacteriastatic in action. It is soluble (Merck 1940) at the rate of 1 gram in 1700 cc. of water at room temperature. It may be obtained only upon prescription from a doctor, dentist or veterinarian.

Experiments on the control of American foul brood with sulfathiazole were begun in Connecticut late in the spring of 1945. The junior author secured infected colonies while making routine spring inspections of apiaries. They were removed to an area isolated from all known apiaries. Eight colonies were used in the experiment. Each of them was known to have been a strong producing unit early in the preceding year. When placed in the experimental yard all contained the characteristic dead larvae, scales and foul odor of the disease (Hambleton 1933). The degree of infection varied but in each case the disease was making serious inroads upon the brood. The morale of the worker bee was affected also, especially in the colonies where the disease had made the greatest progress.

In all treatments sulfathiazole in the form of 0.5 gram tablets was used for ease in handling. Only two formulae were used and they are given as follows:

Formula No. 1. Sugar 1 part,[1] water 1 part: to 1 gallon of this mixture, sulfathiazole 0.5 gram.

Formula No. 2. Water 1 gallon, sulfathiazole 0.5 gram.

The sugar was dissolved thoroughly in warm or hot water and cooled to a handling temperature. The 0.5 gram tablets were ground in a mortar and made into a wet paste before being added to the other materials. Formula No. 1 was always fed to the bees by means of an inverted honey pail, with a perforated top, placed over the opening in the inner cover and pro-

[1] Measured by volume.

tected by an empty super and the hive cover. Formula No. 2 was fed by means of a Boardman feeder which was inserted in one side of the hive opening. As it was desired to have the mixtures available to the bees at all times during the treatment, the containers were examined weekly. Usually 3 or 3.5 pints of Formula No. 1 were given at weekly intervals, and the Boardman feeders were refilled with Formula No. 2 as necessary. If the weather was rainy or cold on the scheduled date, the containers were refilled the next pleasant day.

The first treatments with the sugar-water-sulfathiazole mixture, Formula No. 1, were begun on June 6 and the last made on October 22. This material was accepted readily by every colony to which it was given. In the beginning when the colonies were low on reserves they consumed the quantity given in about three days. However, as the nectar flow and their stores increased, it usually took from five to 10 days for complete consumption. The strength of the colony was also a factor in the rapidity in which the material was consumed. When the colonies approached their peak in mid- and late summer the feeder can was usually emptied in three to four days.

The water-sulfathiazole mixture, Formula No. 2, was accepted and used by the bees in the colonies to which it was available but to a lesser extent than Formula No. 1. More of it was used in poor flight weather than in good weather. As considerably less of the water-sulfathiazole mixture was used, it follows that less sulfathiazole was available in the colonies fed this mixture.

Only one colony was treated by spraying all brood frames with Formula No. 2. This was done at weekly intervals, provided the weather permitted. Usually two frames were removed from the food and brood chambers to permit access to the remainder for spraying. Both sides of the frames in the chambers were sprayed and shifted to one side during the operation. The frames which had been removed were then sprayed and returned to their former position.

Periodic readings were made approximately at two-week intervals to record the progress of each colony. All frames were examined for healthy brood, dead larvae and scales. No attempt was made to count the number of dead larvae or scales in the early stages of the treatments but these were classified in groups as "a great many," "numerous" and "a few." As the conditions in the hives improved and only a few were found on the individual frames, counts were then made to follow the progress of disease elimination more closely.

Definite improvement in the morale of the bees in each colony receiving treatment was noted as occurring between two and three weeks after the initial feeding with the sulfathiazole mixtures. This was indicated by increased activity which approached that of a normal hive. The field workers were bringing in more pollen and honey, while the hive workers were busy with the brood and cleaning out the diseased material. It was noted in the early readings that additional scales would appear in some frames where diseased larvae were too numerous to be removed by the bees between the periods of examinations. This condition changed immediately upon an increased emergence of bees from healthy brood. The increase in hive activity usually resulted in a rapid decrease in the number of diseased larvae and scales.

Diseased larvae and scales were reduced to a minimum in seven to 10 weeks in the colonies continuously treated with Formula No. 1. The scales were usually the first to disappear from the hive, while diseased larvae persisted two to four weeks longer. Scales in the colonies mainly treated with Formula No. 2 usually disappeared almost as rapidly. In the latter case, however, diseased larvae persisted until brood rearing ceased and in one colony typical diseased cells remained after all of the healthy brood had emerged.

In general, hives Nos. 1, 3, 4, 5 and 6, when secured for the experiment, were moderately strong and the disease was making serious inroads upon the brood. Hives Nos. 1, 3 and 4 were low on honey stores and they were fed three times with Formula No. 1. Thereafter only Formula No. 2 was given. At the end of the season and when all healthy brood had emerged, no visual evidence of the disease was present. These three colonies were strong and each contained at least 50 pounds of honey for winter stores. Hive No. 1 had a surplus amounting to 15 pounds, hive No. 3, 25 pounds and hive No. 4, 20 pounds. Hives

Nos. 5 and 6 were fed Formula No. 1 throughout the treatment. These hives were free of all disease on August 13 and remained in a strong healthy condition the remainder of the season. More than 50 pounds of honey was left in each hive for winter stores. Hive No. 5 had a surplus amounting to 35 pounds and hive No. 6, 25 pounds.

Hive No. 2, when the treatment began, was infected heavily with the disease and contained bees sufficient to cover about one frame. This hive received Formula No. 1 throughout the season, with the exception of one week, and also Formula No. 2 during this period. After a slow beginning toward recovery this colony rapidly grew in strength. The colony was free of disease on September 11 and the brood chamber and food chamber were full of bees. No surplus honey was produced but the hive contained at least 60 pounds for winter use.

Hive No. 7, when received, was a strong colony which had begun to store honey, but the morale of the bees was very poor, as the disease was prevalent among the brood. Formula No. 2 was used only as a spray in the treatment of this colony. The scales in the hive were soon eliminated but diseased larvae persisted beyond October 22 when the last observation was made. At the end of the season this colony was very strong in bees and contained more than 50 pounds of honey. Additional honey amounting to 40 pounds was obtained from this hive.

Hive No. 8 was not received until early in July. It was not considered a strong colony, yet contained many more bees than hive No. 2. The disease was in an advanced stage with a great many scales and diseased larvae present. This colony served as an untreated control for the experiment. The morale of the bees was very low and became worse as the incidence of disease became greater. By the first week in October the number of bees had declined to such a point that robbing might occur at any time, so the hive was fumigated with *Cyanogas* and removed from the experimental apiary. It was estimated that less than 10 pounds of uncapped honey remained in the hive.

During the season extra supers (shallow) with frames containing foundation were placed on the hives when required. Each colony completely drew out all frames in at least one super or its equivalent and, with the exception of hive No. 2, completed or nearly completed a second super. The surplus honey from the hives was extracted from each super separately so that samples might be obtained for analysis. Sulfathiazole was found to be present in the extracted honey

Table 1.—Statistics of treatments and results on honeybees with sulfathiazole using water alone and sugar and water as carriers—1945.

Hive No.	Treatment	No. of Frames Infected	Date of First Treatment	Date of Last Treatment	No. of Treatments	Total Amount of Material	Total Sulfathiazole Fed to Bees	Free of Scales	Free of Disease	Sulfathiazole[4] Found in Surplus Honey
						pints	*gms.*			*p.p.m.*
1	Formula No. 1[1]	7	June 6	June 16	3	6	1.4375	Aug. 13	Oct. 8	1
	Formula No. 2[2]		June 23	Oct. 2	11	17				
2	Formula No. 1	6	June 6	Oct. 22	17	49	3.96875	Aug. 13	Sept. 11	0[5]
	Formula No. 2		June 23	Oct. 2	9	14.5				
3	Formula No. 1	5	June 6	June 16	3	6	1.34375	Sept. 24	Oct. 22	4
	Formula No. 2		June 23	Oct. 2	10	15.5				
4	Formula No. 1	3	June 6	June 16	3	6	1.34375	Sept. 11	Oct. 22	6
	Formula No. 2		June 23	Oct. 2	10	15.5				
5	Formula No. 1	4	June 12	Sept. 11	14	45	2.8125	Aug. 13	Aug. 13	18
6	Formula No. 1	5	June 23	Sept. 11	12	39	2.4375	July 31	Aug. 13	10
7	Formula No. 2[3]	13	June 30	Sept. 24	12	22.5	2.0625	Aug. 27	Not free	2.5
	Formula No. 1		Oct. 2	Oct. 22	3	10.5			Oct. 22	
8	Check—no treatment	16	July 16						Cyanided Oct. 8	

[1] Sugar and water (1 to 1 by volume) 1 gal., sulfathiazole 0.5 gms. Placed on top of inner cover in perforated can in empty super.
[2] Water 1 gal., sulfathiazole 0.5 gms. Placed in Boardman feeder in entrance to hive.
[3] Used as a spray on all brood frames.
[4] Preliminary report of analysis made by C. E. Shepard, Conn. Agr. Expt. Sta.
[5] Analysis not available at present date.

of every super taken from the treated colonies. A sample of honey obtained from an untreated hive in another apiary and used as a control gave a negative result when analyzed. As hive No. 2 did not produce a surplus of honey, no sample was taken and an analysis for that colony is not available at this time. The statistics of treatments, results and analysis of the surplus honey are given in table 1.

CONCLUSIONS.—All colonies treated with sulfathiazole at the rate of 0.5 gram to a gallon of mixture, regardless of the method of treatment, reacted favorably to some degree. It was found that when sulfathiazole was used at the rate of 0.5 gram to one gallon of water the mixture was not consumed in quantities sufficient to eliminate the disease entirely in a single season.

Likewise, when sulfathiazole at the rate of 0.5 gram to one gallon of water was used as a spray on all brood frames at weekly intervals for 12 weeks, insufficient quantities of the medication were deposited or consumed to eliminate the disease.

When sulfathiazole was used at the rate of 0.5 gram in one gallon of equal parts of sugar and water, it was found that the mixture was more attractive to the bees, resulting in a higher consumption which supplied sufficient medication to eliminate the disease in less than one season.

It was found that when sulfathiazole was used as a medication it would be deposited in the honey stored by the bees. Also that the amount deposited in the honey increased with increased consumption of the mixtures fed to the bees. As the greatest quantity found in the few samples analyzed amounted to only 20 p.p.m., or 9.07 mg. per pound of honey, and as treatment of man is in grams per day, a large safety factor exists.

The writers concur with Haseman & Childers in that fall treatments after the surplus honey is taken off the colonies and spring treatments before surplus honey is being made are desirable, especially if the disease can be eliminated in those periods.

It is fully realized that the conclusions drawn in this paper are based on one season's work. However, the colonies of bees concerned will be under close observation for the next two or three years.

Beekeepers, if using sulfathiazole, should confine their efforts strictly to an experimental basis until definite recommendations are made to them by state or federal authorities. All honey produced in colonies treated with sulfathiazole should be kept out of all commercial channels until tolerances are established. If honey containing sulfathiazole is permitted to go into the usual trade channels before such action is taken, such might result very unfavorably to the honey industry.

If the treatment of bees for American foul brood with sulfathiazole is found to be entirely feasible on a practical basis, beekeepers will no longer have to destroy their bees and hive equipment as in the past. Successful application in the field will indeed prove a boon to the bee industry.

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Effect of Calcic and Magnesic Diluents of Calcium Arsenate On Bean Yields[1]

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A review of the literature shows that investigators have arrived at divergent conclusions as to the toxicity of calcium arsenate to beans. List (1921), Bobb (1935), Howard & Mason (1936), and Sherman & Todd (1939) considered calcium arsenate as unsafe to use on bean foliage. On the other hand, Eddy & McAllister (1927) and Douglas (1933) reported calcium arsenate as a safe insecticide for use on beans. Howard & Fletcher (1931) found five commercial brands of calcium arsenate to be nontoxic, five brands intermediately safe and nine brands to be unsafe to use on bean foliage.

Calcium arsenate in combination with several diluent materials was applied in dust form to beans in preliminary experiments by the author during 1933 and 1934. The diluents included talc, diatomaceous earth, bentonite, sulfur, flour, hydrated spray lime and clay. Of these, the best results from the standpoint of safety to bean foliage were obtained when hydrated spray lime was the diluent. Consequently it was decided to investigate hydrated spray lime as a diluent for calcium arsenate when applied in dust form to beans.

Two forms of hydrated spray lime were used in the experiments: (1) high calcic hydrated spray lime containing 72 per cent calcium, expressed as calcium oxide, and less than 0.5 per cent magnesium; (2) high magnesic hydrated spray lime containing 46 per cent calcium, expressed as calcium oxide, and 32 per cent magnesium expressed as magnesium oxide. High calcic and high magnesic lime were also combined with monohydrated copper sulfate as diluents for calcium arsenate. The data cover a period of 1935 to 1945 with certain years omitted because of failure to secure an even stand of bean plants in some of the plots. Replications of 10 plots for each treatment and untreated check plots arranged at random were maintained in the trials. One part of calcium arsenate was combined with 7 parts of the diluents, except during 1942 and 1944 when the ratio was one part of calcium arsenate to nine parts of diluent, and during 1943 when one part of calcium arsenate and 10 parts of the diluents were used. The diluents consisted of the high calcic and high magnesic spray lime already referred to. Monohydrated copper sulfate, when used, was combined with one or the other of the spray limes referred to in the foregoing at the rate of one part copper to four of lime. In general, amounts of material used and number of applications made to the beans in those experiments were in excess of those required for effective control of the Mexican bean beetle. The effect of the insecticides on beans in the plots was evaluated mainly on the basis of yield, since there was not always a consistent correlation between the amount of apparent foliage injury and final yield.

Bean yields from plots receiving treatments of calcium arsenate and high calcic lime were compared with yields from untreated check plots (Fig. 1). There were decreases in yield for 5 of the 6 years during which this material was used. For 1941 and 1944 the decreases amounted to 43.9 and 46.5 per cent respectively, which according to statistical analysis were highly significant. There was a decrease of 25.6 per cent for 1940, and the six-year average decrease in bean yields for plots treated with calcium arsenate and high calcic lime was 21.9 per cent. During the year of 1937 there was an increase of 10.3 per cent in bean yield in the plots treated with this material which was not significant at the 5-per cent level.

Data were obtained on bean yields as affected by treatments of calcium arsenate and high magnesic hydrated lime as compared with yields from untreated check plots for a period of six years (Fig. 1). The increase of 65.6 per cent in yield during 1942 was highly significant. The decrease of 21.4 per cent during 1944 was also significant. The average increase for

[1] Credit is due Miss Mildred Covell, Technical Assistant, Maine Agricultural Experiment Station, for her able assistance and advice concerning statistical analysis of the material involved in this paper. Also, credit is due Mr. J. J. Devitt for assistance in field work and analyzing of data during 1943 and 1944.

the six years was 11.1 per cent in the yield of beans harvested from all plots treated with calcium arsenate and high magnesic hydrated spray lime over that of untreated check plots.

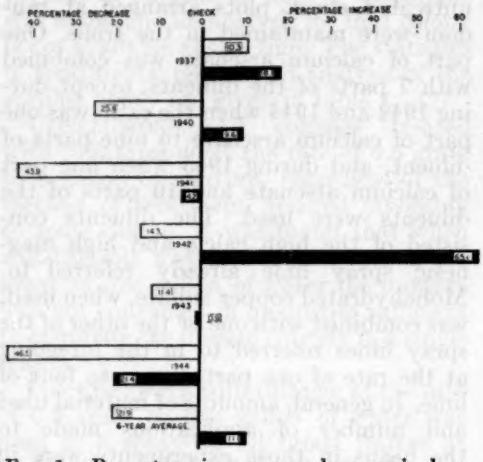

FIG. 1.—Percentage increase or decrease in bean yields resulting from the use of high calcic lime and high magnesic lime diluents of calcium arsenate as compared with bean yields from untreated check plots. White bars represent percentages of increase or decrease resulting from the use of high calcic lime and black bars those resulting when high magnesic lime was the diluent. Numbers within the bars represent actual percentages increase or decrease. The year is shown at the left of the base line between each of the paired bars representing the results for each year.

Bean yields from plots treated with calcium arsenate, monohydrated copper sulfate and high calcic hydrated lime were compared with yields from untreated check plots over a seven-year period (Fig. 2). An outstanding and significant increase in yield of 85.5 per cent was obtained from the plots treated with this insecticide during 1942. For 6 of the 7 years there were decreases in yield of beans from the plots treated with calcium arsenate, monohydrated copper sulfate and high calcic lime. In spite of this the average seven-year increase in yield for all the plots receiving treatments of calcium arsenate, monohydrated copper sulfate, and high calcic lime over the untreated check plots was 1.5 per cent which is not significant according to statistical analysis. The increase in yield in the treated plots during 1942 is explainable on the basis of the excessive amount of injury caused by the Mexican bean beetle in the plots receiving no treatment during the year.

Bean yields from plots treated with calcium arsenate diluted with monohydrated copper sulfate and high magnesic lime compared with the yields from untreated check plots over a seven-year period

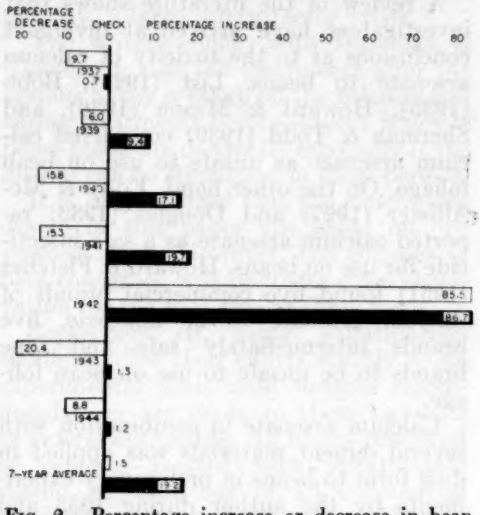

FIG. 2.—Percentage increase or decrease in bean yields resulting from the use of high magnesic and high calcic lime diluents of monohydrated copper sulfate and calcium arsenate as compared to bean yields from untreated check plots. White bars represent increase or decrease in bean yield from the use of high calcic lime and black bars represent increase or decrease in yield when high magnesic lime was the diluent used.

were greater than those from check plots for six of the seven years (Fig. 2). A significant increase of 86.7 per cent in bean yield was obtained for the year of 1942, an increase due at least in part to protection from a heavy attack by the Mexican bean beetle. The increase of 19.7 per cent during 1941 also trended toward significance. The decrease in the treated plots of 0.7 per cent in yield below that of the untreated check plots during 1937 was not significant. The average increase in yield for seven years for all plots treated with calcium arsenate, monohydrated copper sulfate and high magnesic hydrated spray lime was 19.2 per cent.

Bean yields from plots treated with high magnesic hydrated lime and calcium arsenate were directly compared with bean yields from plots treated with high calcic hydrated lime and calcium arsenate (Fig. 3). The data cover a period of six years. In every case the use of high magnesic lime resulted in an increase in

percentage of the yield over that obtained when high calcic lime was the diluent used for calcium arsenate. Percentage increases in yield from plots receiving treatments of high magnesic lime and calcium arsenate over those in which high calcic lime was the diluent used ranged from the low of 7.8 during 1937 to the high of 79.9 in 1942. The average increase for the plots receiving the high magnesic lime diluent was 33 per cent.

Bean yields from plots treated with calcium arsenate, high magnesic lime and monohydrated copper sulfate were compared directly with those from plots treated with high calcic lime, calcium

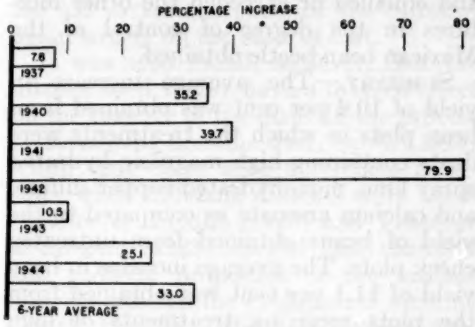

FIG. 3.—Percentage increase or decrease in bean yields resulting from the use of high magnesic lime and calcium arsenate directly compared to bean yields resulting from the use of high calcic lime and calcium arsenate. The bars represent the percentage increase in bean yield when the diluent was high magnesic lime over the bean yield when the diluent for calcium arsenate was high calcic lime. Dates are shown directly beneath the bars.

arsenate and monohydrated copper sulfate (Fig. 4). Data obtained for seven years show that bean yields from plots treated with high magnesic lime were increased from the percentages ranging between 1.2 to 35 over the yields from plots treated with the mixture containing the high calcic lime. The seven-year average increase in yield of 17.6 per cent was obtained when high magnesic lime was used on beans in place of high calcic lime in the combinations of calcium arsenate, monohydrated copper sulfate and lime.

Bean yields from plots treated with calcium arsenate, monohydrated copper sulfate and high magnesic lime were compared with yields from plots treated with calcium arsenate and high magnesic lime for 6 years (Fig. 5). Increases in yields occurred for five of the six years during

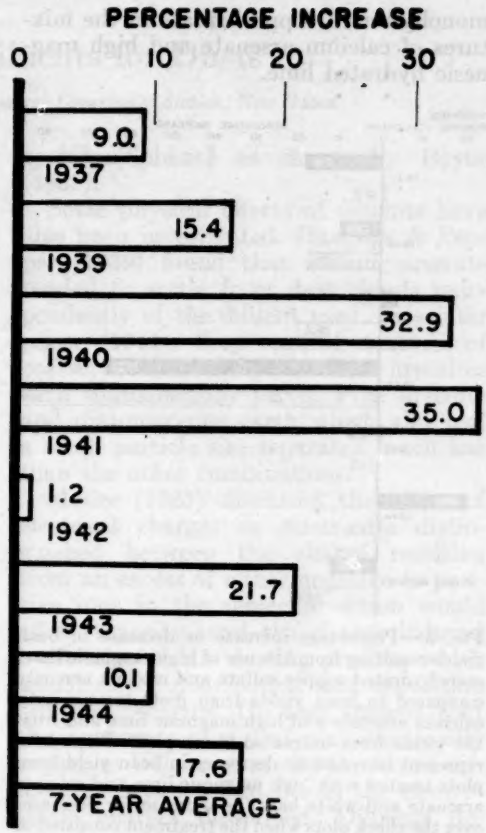

FIG. 4.—Percentage increase in bean yields resulting from the use of high magnesic lime, monohydrated copper sulfate and calcium arsenate compared directly to bean yields resulting from the use of high calcic lime, monohydrated copper sulfate and calcium arsenate. The bars represent the percentage increase in bean yields resulting from the use of high magnesic lime, monohydrated copper sulfate and calcium arsenate over those from the plots treated with high calcic lime, monohydrated copper sulfate and calcium arsenate. Dates are shown directly beneath the bars.

which the comparisons were made, in plots receiving the insecticide containing the monohydrated copper. The 7-year average increase in percentage obtained in bean yields from plots to which were applied the materials containing copper sulfate was 20.9 per cent. The 6-year average increase in yield of beans harvested from the plots as a result of using the calcium arsenate and high magnesic hydrated lime was 11.0 per cent over that of the yield from the check plots. The difference of 9.8 per cent represents the average increase for this period for yield of beans from plots containing the

monohydrated copper sulfate in the mixtures of calcium arsenate and high magnesic hydrated lime.

FIG. 5.—Percentage increase or decrease in bean yields resulting from the use of high magnesic lime, monohydrated copper sulfate and calcium arsenate compared to bean yields from plots treated with calcium arsenate and high magnesic lime and from the yields from untreated check plots. Black bars represent increases or decreases in bean yield from plots treated with high magnesic lime and calcium arsenate and white bars the increases or decreases over the check plots when the treatment consisted of high magnesic lime, monohydrated copper sulfate and calcium arsenate. Dates are shown between the bases of the paired bars.

The 20–80 monohydrated copper sulfate, high magnesic lime dust 9 parts to 1 part of calcium arsenate was satisfactory when applied to bean foliage and slightly more toxic to the Mexican bean beetle than the 1 to 10 mixture of these materials.

The decrease in the yield of beans from the plots receiving insecticidal treatments was most noticeable during years of light Mexican bean beetle infestations. This was due to the toxic effect of the insecticides on the bean plants in the treated plots being greater than benefits derived from protection against injury by the pest during these years. When the Mexican bean beetle was abundant, the toxic effects upon the beans were more than counterbalanced and were masked by the benefits derived from control of the pest. The high magnesic lime, monohydrated copper sulfate, and calcium arsenate mixtures were least toxic to the bean plants and equalled or exceeded the other mixtures in the degree of control of the Mexican bean beetle obtained.

SUMMARY.—The average increase in yield of 19.2 per cent was obtained from bean plots in which the treatments were dusts containing high magnesic hydrated spray lime, monohydrated copper sulfate, and calcium arsenate as compared to the yield of beans obtained from untreated check plots. The average increase in bean yield of 11.1 per cent was obtained from the plots receiving treatments of high magnesic lime and calcium arsenate as compared to the yield of beans harvested from the untreated check plots and the increase of 1.2 per cent was obtained when the beans were treated with high calcic lime, monohydrated copper sulfate and calcium arsenate.

There was an average decrease of 21.9 per cent in yield of beans from the plots treated with dusts containing high calcic lime and calcium arsenate as compared with bean yield from untreated check plots.—1-19-46.

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Diatomaceous Diluents for Dusts[1,2]

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The chief purpose of a diluent in a dusting mixture is to reduce the amount of toxicant applied. Thus Petch (1917) commented on the high cost of dusting with pure arsenate of lead, and studied materials which might be used as diluents. He included in his list many materials available locally and suggested five mostly on the basis of price. As dusts and dusting were investigated more intensively, other materials were selected for use in various parts of the country, again largely on the basis of cost.

It was soon found, however, that the diluent used might have a marked effect on the toxicity of the dust. In the process of developing nicotine dust, Smith (1921) found that there were differences in results when different diluents were used. Headlee & Rudolfs (1923) and Thatcher & Streeter (1923) showed that chemical and physical properties of the various diluents affected the evolution of nicotine and the toxicity of the dust. Boyce (1933) found differences in toxicity of cryolite and barium fluosilicate (1934), and dinitro-o-cyclohexylphenol (1938) used with different diluents. Dietz & Zeisert (1934) noted similar effects with lead arsenate, calcium arsenate and barium fluosilicate dusts. Huckett (1934) and Walker & Anderson (1934) reported that diluents affected the toxicity of derris in dusts, Huckett (1940) of pyrethrum, Carruth (1943) of nicotine bentonite and Pepper & Carruth (1945) of ground *Ryania*.

In the course of the investigations cited above, the reasons for some of the effects were determined. Alkaline diluents were preferred for dusts containing nicotine sulfate because they freed the nicotine. Alkaline diluents were detrimental to the arsenicals and the fluorine compounds, presumably because they reacted to form less toxic compounds. Similarly alkaline materials affected rotenone-bearing dusts, as demonstrated by Allen & Brooks (1940) and dinitro-o-cyclohexylphenol as shown by Boyce (1938).

Some physical effects of diluents have also been investigated. Hastings & Pepper (1939) found that sodium arsenite tended to settle from dust clouds independently of the diluent used. In a later paper (1941), they studied mixtures of coarse, medium and fine sodium arsenites with diatomaceous earth. Fine arsenite and diatomaceous earth which also had a small particle size separated much less than the other combinations.

Moore (1925) discussed the effect of electrical charges on dusts. He distinguished between the charge resulting from an excess of either negative or positive ions in the molecule which would affect tenacity, and the charge induced by friction in the dusting process, which would affect distribution and deposition but not tenacity. He also showed that the epidermis of a leaf was electrically negative. Wilson et al. (1941) found differences between diluents in the electrostatic charges developed. Diluents developing a high electrostatic charge when mixed with ground derris root produced greater mortality of aphids. MacLeod & Smith (1943) collected dusts on charged plates. Plant products, the arsenicals, barium fluosilicate, calcium carbonate, gypsum and some sulfurs were attracted to the negative plate more than to the positive. Clays, diatomites, copper cyanide, cryolite, soapstone, and some sulfurs were attracted to the positive plate. Mixing powders resulted in higher deposition, but the result could not be predicted from a study of the two ingredients.

The tenacity of dusts has received much attention. Moore (1925) reported that a positively charged calcium arsenate dust resisted washing much better than ordinarily calcium arsenate. Voelkel (1929) tested 78 materials and found no wide range of tenacity. The material which was left following weathering was frequently only the diluent. Many workers have added materials to increase tenacity. These will not be discussed here.

[1] These investigations were supported in part by a grant from the Johns-Manville Corporation through the Crop Protection Institute.

[2] Awarded the Annual Eastern Branch Award as the Outstanding paper presented at the Seventeenth Annual Meeting.

Much of the work done with diluents has involved testing a large group of materials from various sources. This approach has resulted in the selection of a few superior diluents. There has been, however, little opportunity to study the effect of chemical and particularly physical properties of a series of similar materials. The availability of a number of diatomaceous earths from various deposits, and of a series of materials from the same deposit processed in a different manner offered an opportunity for a further study of the effect of diluents on toxicants.

Diatomaceous earth has been used by many investigators. Some have found it superior to, some equal to and some inferior to other diluents. Since the materials were not identified either as to origin or to method of preparation, little could be accomplished by an extended review of the literature. However, MacLeod and Smith found that two diatomites were attracted strongly to positive plates; in other words they were highly charged.

The series of diatomaceous earths studied were selected and prepared by the Johns-Manville Research Laboratory. They are laboratory preparations of different types of earth prepared by different methods to produce the physical and chemical characteristics given in table I. The samples are described as follows:

Identification of Samples of Diatomaceous Materials Tested[1]

Sample No.

52 Fine particle size natural diatomaceous powder, with faintly alkaline characteristics.

53 Milled natural diatomaceous powder; intermediate particle size; substantially neutral; Grade A.

54 Milled natural diatomaceous powder: intermediate particle size: substantially neutral; Grade B.

55 Milled natural diatomaceous powder; intermediate particle size; substantially neutral; Grade C.

56 Milled natural diatomaceous "clay"; coarser particle size; substantially neutral.

57 Special milled natural diatomaceous product; coarser particle size; substantially neutral.

58 Extremely fine particle size natural diatomaceous powder; substantially neutral.

59 Fine particle size calcined diatomaceous powder; substantially neutral.

60 Fine particle size diatomaceous powder; with electropositive characteristics.

61 A synthetic silicate product; substantially neutral.

62 Another synthetic silicate product; faintly alkaline.

63 Milled natural diatomaceous powder; intermediate particle size; substantially neutral; Grade D.

67 Fine particle size natural diatomaceous powder; substantially neutral.

69 Milled natural diatomaceous powder intermediate particle size; slightly acidic; Grade E.

[1] Data furnished by the Johns-Manville Research Laboratory. The writer acknowledges the assistance of A. B. Cummins and H. L. King, Jr. in furnishing the information and for the data in Table I.

Table 1.—Characteristics of samples of diatomaceous earth diluents.

Sample No.	Loose Wt. Lbs./Cu. Ft.	Moisture Per Cent	Per Cent Retained 325 Mesh Wet Screen	pH (Water =5.7)
52	8.4	3.4	0.4	10.0
53	8.0	3.0	6.6	5.8
54	7.9	3.2	3.3	5.7
55	16.8	3.0	10.3	5.8
56	24.4	3.4	29.7	5.5
57	18.1	4.4	7.0	6.0
58	8.4	3.0	.1	6.8
59	8.3	.6	2.2	6.0
60	12.7	2.6	.1	4.9
61	14.3	8.0	6.1	7.4
62	7.4	5.0	14.0	9.2
63	12.1	3.0	6.8	6.3
67	8.2	2.2	.1	5.7
69	9.0	2.6	17.1	3.9

The purposes of the portions of these investigations reported here were (1) to attempt to determine the reasons for differing performances of diluents with toxicants and (2) to study laboratory methods which might apply to this type of problem.

LABORATORY PROCEDURE.—Samples were mixed with pure ground derris root in a dosage series of concentrations. A pyrophyllite (*Pyrax ABB*) was used as the standard, with 0.125 per cent, 0.25 per cent, 0.5 per cent and 1 per cent rotenone. The diatomaceous earth samples were mixed by volume, as suggested by Huckett (1940). Most of the samples of diatomaceous earth weighed much less per cubic foot than pyrophyllite. Moreover, the particle size distribution of the pyrophyllite (91.2 per cent 7 microns or less in diameter, as stated in a pamphlet published by the manufacturer) was about the same as the fine diatomaceous

diluents (at least 90 per cent below 10 microns). The greater bulk of the diatomaceous earths could be caused by different particle shape or different density. Microscopical examination of the extremely fine particles disclosed no unusual shape to account for the difference in bulk. In order to provide an equal *number* of particles of diluent, the materials were mixed by volume. Use of weight as a criterion would have used many times more particles of the diatomaceous diluents. Mixing was done in a shaker provided with screens to act as baffles. The dusts were applied to *Aphis rumicis* L. on nasturtium leaves, using the settling tower devised by Heuberger & Turner (1942). The dusted leaves were kept for 24 hours in a constant temperature room (75°F., 65 per cent R. H.) and the mortality determined.

Tenacity was determined by a modification of the method of Heuberger (1940). Clean glass lantern slides were cleaned, dried and weighed. They were then sprayed with water for 20 seconds in a precision sprayer and exposed to the pure diluent dusted in the settling tower. After drying and weighing, the slides were washed by swishing them through cold water in a large pan. A logarithmic series of strokes of from one to sixteen was used so that the comparisons could be made on the basis of the washing required to remove a given proportion of the deposit. After washing, the slides were dried and reweighed to determine the amount remaining.

FIELD PROCEDURE.—Mixtures of selected diluents with pure ground cube root and with cryolite were used. Plots were 10 feet long in the case of beans, and 10 plants long with cabbage. Dusts were applied early in the morning using a hand duster, usually the rotary type. There were three replicates in all cases. Results were obtained by counting the surviving bean beetles and by estimating the damage to cabbage (Turner 1943).

LABORATORY TESTS.—The samples of diatomaceous earth were tested on aphids as described, using a pyrophyllite standard with each run, and with three replicates with each material. The percentage killed by each concentration was obtained from the percentages of the individual tests by average. This method may be open to question. Totalling the numbers dead and alive, however, is open to more question, since it weighs heavily in favor of the tests with a larger number of aphids.

Detailed data for the group of materials selected for field test are given in table 2, and dosage response curves in figures 1 and 2. Similar dosage response curves have been prepared for the rest of the samples.[1] Since it serves little purpose to publish the detailed data for the ineffective materials, the results have been

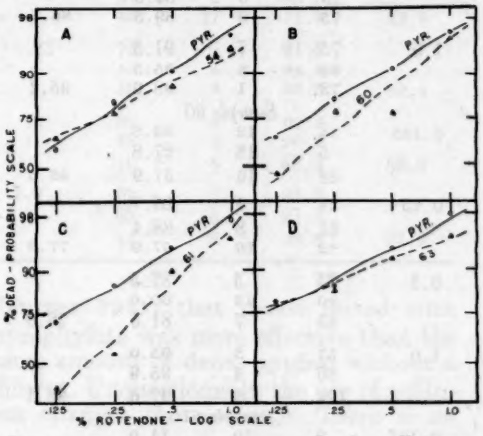

FIG. 1.—Dosage-response curves for four diatomaceous diluents compared with pyrophyllite on *Aphis rumicis* in the laboratory.

presented in summary in table 3, in terms of the concentration required to kill 90 per cent of the aphids. It will be seen that Sample 69 was slightly more effective than pyrophyllite. Samples 54

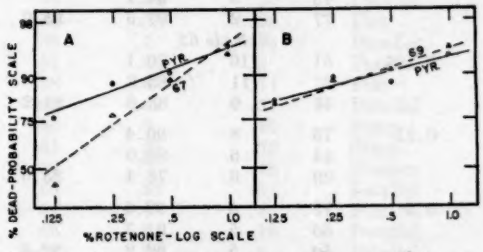

FIG. 2.—Dosage-response curves for two diatomaceous diluents compared with pyrophyllite on *Aphis rumicis* in the laboratory.

and 63 approached pyrophyllite closely and produced parallel slopes, and Samples 60 and 61 were less effective than pyrophyllite but had steeper slopes.

[1] The detailed data are in the files of the Connecticut Agricultural Experiment Station, New Haven, Conn., and are available for study.

Table 2.—Laboratory tests of diatomaceous earths with derris on *Aphis rumicis*

Per Cent Rote-none	No. Dead	No. Alive	Per Cent Dead	Average Per Cent Dead	Per Cent Rote-none	No. Dead	No. Alive	Per Cent Dead	Average Per Cent Dead
	Sample 54					*Pyrax ABB*			
0.125	63	21	75.0		.125	36	32	52.9	
	28	16	63.3			19	10	65.5	
	24	20	54.5	64.4		33	22	60.0	59.5
0.125	72	16	81.8		.25	74	12	86.0	
	28	12	70.0			17	5	77.3	
	58	13	81.7	77.8		110	27	80.3	81.2
0.5	44	6	88.0		.5	72	6	92.3	
	29	6	82.9			24	4	85.7	
	75	9	89.3	86.7		103	6	94.5	90.8
1.0	75	7	91.5		1.0	71	2	97.3	
	63	3	95.5			48	2	96.0	
	73	1	98.6	95.2		84	4	95.5	96.3
	Sample 60					*Pyrax ABB*			
0.125	14	12	53.8		.125	16	8	66.7	
	5	13	27.8			41	15	73.2	
	22	16	57.9	46.5		36	32	52.9	64.3
0.25	24	4	85.7		.25	26	8	76.5	
	61	8	88.4			52	12	81.3	
	22	16	57.9	77.3		74	12	86.0	81.3
0.5	35	5	87.5		.5	26	3	89.7	
	20	13	60.6			74	6	92.5	
	49	7	81.5	76.5		72	6	92.3	91.5
1.0	57	3	95.0		1.0	58	3	95.1	
	86	4	95.6			91	2	97.8	
	122	3	97.6	96.1		71	2	97.3	96.7
	Sample 61					*Pyrax ABB*			
0.125	8	59	11.9		.125	31	12	72.0	
	20	43	31.7			20	13	60.6	
	40	18	69.0	37.5		64	14	82.1	71.6
0.25	39	19	67.2		.25	50	12	80.6	
	20	54	27.0			28	4	87.5	
	56	21	72.7	55.6		75	7	91.5	86.5
0.5	30	4	88.2		.5	39	4	90.7	
	49	6	89.1			61	3	95.3	
	35	3	92.1	89.8		95	3	96.9	94.3
1.0	99	4	96.1		1.0	77	2	97.5	
	48	3	94.1			64	2	97.0	
	77	2	97.5	95.9		98	1	99.0	97.6
	Sample 63					*Pyrax ABB*			
0.125	51	16	76.1		.125	31	10	75.6	
	57	11	83.8			67	16	80.7	
	46	9	83.6	81.2		50	11	82.0	79.4
0.25	75	8	90.4		.25	49	7	87.5	
	44	6	88.0			32	7	82.1	
	29	8	78.4	85.6		40	5	88.9	86.2
0.5	73	5	93.6		.5	81	4	95.3	
	55	5	91.7			71	4	94.7	
	59	5	92.2	92.5		60	4	93.8	94.6
1.0	58	2	96.7		1.0	80	1	98.8	
	53	2	96.4			56	1	98.2	
	66	3	95.7	96.3		65	2	97.0	98.0
	Sample 67					*Pyrax ABB*			
0.125	5	24	17.2		.125	50	11	82.0	
	20	20	50.0			25	7	78.1	
	34	23	59.6	42.3		57	24	70.4	76.8
0.25	37	7	84.1		.25	40	5	88.9	
	32	8	80.0			30	5	85.7	
	35	16	68.6	77.6		45	6	88.2	87.6

Table 2.—(Continued)

Per Cent Rotenone	No. Dead	No. Alive	Per Cent Dead	Average Per Cent Dead	Per Cent Rotenone	No. Dead	No. Alive	Per Cent Dead	Average Per Cent Dead
0.5	54	10	84.4		.5	60	4	98.3	
	33	4	89.2			39	4	90.7	
	53	4	93.0	88.9		54	5	91.5	92.0
1.0	40	4	90.9		1.0	65	2	97.0	
	50	2	96.2			41	3	93.2	
	69	3	95.8	94.3		49	2	96.1	95.4
		Sample 69					*Pyrax ABB*		
0.125	23	4	85.2		.125	103	21	83.1	
	58	13	81.9			31	2	93.9	
	24	7	77.4	81.5		43	17	71.7	82.9
0.25	42	5	89.4		.25	75	7	91.5	
	71	9	88.8			58	4	93.5	
	32	4	88.9	89.0		40	8	83.3	89.4
0.5	47	5	90.4		.5	37	3	92.5	
	57	5	91.9			28	3	90.3	
	61	5	92.4	91.6		19	4	82.6	88.5
1.0	89	2	97.8		1.0	36	1	97.3	
	60	4	93.8			43	4	91.5	
	94	4	94.4	95.3		45	3	93.8	94.2

It will be noted that there was a variation of from .18 to .46 per cent rotenone required to kill 90 per cent of the aphids in the tests with pyrophyllite (Table 3). Much of this variation was caused by an actual variation in susceptibility of the aphids. It was noticed that aphids were much more easily killed following a few days of cloudy weather, accompanied by a high humidity. This emphasizes the necessity of using a standard material with each unknown in order to arrive at reasonably accurate comparisons.

According to Dimond *et al.* (1941) slope is a property of the toxicant when all other factors are held constant. Slope may also be affected by the type, age and condition of the test organism, or by coverage. In this case the test insects were all taken from the same culture for each test. This should eliminate all possibilities except change in toxicant and coverage. This cannot be tested biologically because of the coverage factor. Derris can be dusted without any diluent, but the addition of the diluent changes the coverage. In this case we are comparing the slopes of dosage-response curves of derris with two diluents. When the resulting curves are parallel, the overall effects of one are the same as the overall effects of the other. Unfortunately these two effects cannot be measured by the methods used. It has been shown (Turner 1943) that derris mixed with pyrophyllite was more effective than the same amount of derris applied without a diluent. Unquestionably the use of a diluent changes the coverage. There is no indication, however, that pyrophyllite *decreased* the toxicity of derris. In this case we are comparing the slopes of dosage-response curves of derris mixed with two diluents, one of which was used as a standard. When the curves are paral-

Table 3.—Per cent rotenone required to kill 90 per cent of the Aphids.

Sample No.	Diatomaceous Earths	Pyrophyllite	Slope Relative to Slope for *Pyrax ABB*
52	.58	.45	Flat
53	.7	.5	Flat
54	.52	.5	Parallel
55	.55[1]	.28	Flat
56	.7	.46	Parallel
57	.64	.3	Parallel
58	.6	.44	Flat
59	.62	.5	Parallel
60	.6	.42	Steep
61	.57	.35	Steep
62	.7	.18	Steeper
63	.32	.3	Parallel
67	.7	.4	Flat
68	.8	.18	Parallel
69	.32	.4	Parallel

[1] Much less toxic than derris-pyrophyllite. Direct comparison was impossible.

lel, the over-all effects of one are the same as the over-all effects of the other. When the slope is changed, the cause may be coverage or a chemical effect on the toxicant and nothing in the data available indicates which factor is involved. The high pH of Sample 52 might be responsible for the flat slope produced, but high pH of Sample 62 did not flatten the slope.

It is noteworthy that Samples 52, 58, 60 and 67 reduced the toxicity and that all were composed of extremely fine particles. All but Sample 60 flattened the slope. The fine particles of these materials may have coated the particles of derris so that there was less intimate contact between toxicant and insect. According to Horsfall (1945) this type of action should not affect the slope. All that can be concluded from the particle-size and toxicity data is that extremely fine particle-size is not necessary for a diluent for ground derris root.

Fortunately it is possible to select diluents from this group of materials without exact knowledge of what has changed the slope. It is desirable when possible to use materials producing a steep slope, and if toxicity is to be improved, one with the curve plotting to the left of the standard. In this case Sample 69 was the only material producing a curve plotting to the left of the pyrophyllite standard.

TENACITY.—Tenacity was determined as described above. Two replicates were run for each material. If these did not agree fully, two more were completed. Data were summarized and plotted with number of strokes of washing as dosage and per cent remaining as response. Bancroft clay was used as the "standard" material because it has been found to be one of the more tenacious diluents.

Detailed data for the representative materials chosen for field tests are presented in table 4, and dosage-response curves in figures 3 and 4. Data for the other materials have been plotted in like manner, and the strokes required to remove a given percentage interpolated from the curves (Table 5). It will be noted that samples 52, 55, 57, 60, 61, 62 and 63 were more tenacious than Bancroft clay because more washing was required to remove the stated percentage. Moreover, three types of curves resulted, flatter than, steeper than, and parallel with curves for Bancroft clay. A flat curve represents a broad spread between amounts of washing necessary to remove a comparatively small proportion of the deposit. A flat slope is an ideal requirement for materials requiring a high tenacity, because the residue remaining after washing is of greatest importance.

Table 4.—Tenacity of diatomaceous earths compared with Bancroft clay.

MATERIAL	PER CENT TENACITY—NUMBER STROKES WASHED				
	1	2	4	8	16
54	44.8	35.0	28.3	13.2	12.8
	74.6	50.7	36.7	25.2	30.6
	18.7	16.1	8.2	5.6	5.2
	29.7	6.1	4.5	4.0	4.2
Average	41.9	27.0	19.4	12.0	13.2
Bancroft Clay	63.8	47.5	47.9	33.1	28.6
	52.8	45.9	37.9	27.3	32.6
	43.7	35.1	24.9	16.9	13.5
Average	54.1	42.8	36.9	25.8	24.9
60	50.3	43.9	42.4	36.0	28.3
	53.5	38.3	34.4	28.0	23.0
	29.2	41.3	18.7	22.3	20.6
	36.3	32.4	8.8	19.6	69.9
Average	42.4	39.0	26.1	26.5	37.9
Bancroft Clay	65.8	47.5	47.9	33.1	28.6
	50.3	39.1	34.6	30.0	29.8
	43.7	35.1	24.9	16.9	13.5
Average	53.3	40.6	35.8	26.7	24.0
61	65.0	57.0	57.0	50.3	59.6
	40.4	35.4	34.0	37.9	28.5
Average	52.7	46.2	45.5	39.1	44.1
62	85.9	80.7	83.7	84.3	79.2
	70.0	76.1	73.2	70.1	77.3
Average	77.9	78.4	78.5	77.2	78.3
Bancroft Clay	68.4	63.3	14.6	34.1	28.5
(for 61 and 62)	50.3	39.1	34.6	30.0	29.8
Average	59.4	51.2	24.6	32.1	29.2
63	82.9	74.5	68.8	63.8	61.6
	67.2	60.2	56.5	63.9	49.5
Average	75.1	67.4	52.7	63.9	55.6
Bancroft Clay	68.4	63.3	14.6	34.1	29.5
	53.4	40.4	33.7	—	23.0
Average	60.9	51.9	29.2	34.1	25.8
67	24.2	24.2	39.7	23.5	18.4
	31.5	27.3	1.9	24.4	18.4
Average	27.9	25.8	20.8	24.0	18.4
Bancroft Clay	52.9	38.3	33.6	35.1	25.7
	53.4	40.4	33.7	—	23.0
Average	53.2	39.4	33.7	35.1	24.4
69	33.9	15.6	7.4	3.9	4.5
	22.4	17.0	7.4	6.0	2.6
Average	28.2	16.3	7.4	4.9	3.5
Bancroft Clay	51.1	44.3	39.3	36.4	30.1

As Dimond *et al.* (1941) have pointed out, the relative effectiveness of two materials with crossing dosage-response curves is reversed by the crossing. Within the range of this test one material, 60, crossed with the curve for Bancroft clay.

At levels below the cross-over, clay was more tenacious, above the cross-over, 60 showed higher tenacity. The amount of

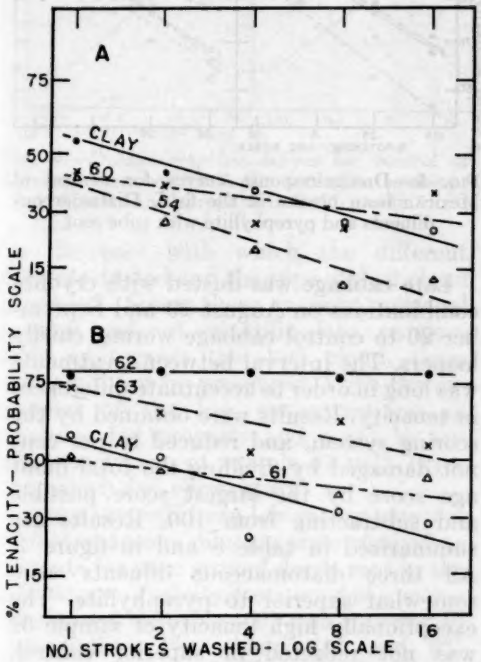

FIG. 3.—Tenacity curves for diatomaceous diluents compared with Bancroft clay. Glass slides in laboratory tests.

rainfall, then, would determine which material would have better tenacity in the field. Samples 61, 62 and 63 were

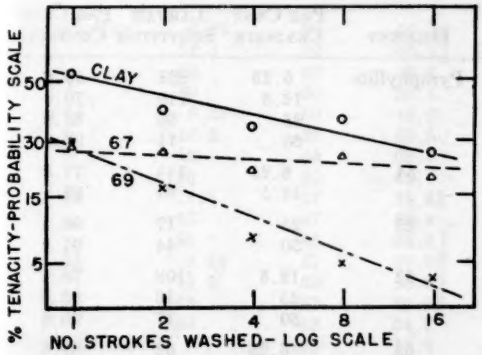

FIG. 4.—Tenacity curves for diatomaceous diluents compared with Bancroft clay. Glass slides in laboratory tests.

much more tenacious than clay, and all had flatter dosage-response curves.

The variations in tenacity of Bancroft clay (Table 5) are considerable and must be caused by variations in manipulation.

SELECTION OF MATERIALS FOR FIELD TESTS.—On the basis of the laboratory tests, materials were selected for field tests. For cube, these included 69, which was more effective, and 54 and 63, which were about equal to pyrophyllite. Samples 60 and 61 were chosen because their toxicity curves were steeper than pyrophyllite curves and because both were relatively tenacious.

Table 5.—Tenacity ratings of diatomaceous earths.

SAMPLE	Per Cent	STROKES REQUIRED TO REMOVE: Diatomaceous Earth Sample	Bancroft Clay
52	65	16	6
53	60	1	3
54	60	.8	3
55	60	15	3.5
56	60	3	8
57	60	17	7.5
58	60	3	7.5
59	60	4	4
60	70	9	7
61	60	20	3.5
62[1]			
63	50	40	1.5
67	70	1.2	7.0
69	70	1	20.0
Loomkil Talc	70	2.5	13
Cherokee Clay	70	11	13

[1] Loss did not exceed 22 per cent, no direct comparison possible. By far the most tenacious material tested.

For cryolite the principal criterion was tenacity. Samples 62 and 63 were chosen, although 62 had a high pH. For comparison 54 and 67 were also chosen, the former because it was more tenacious than 69 and was compatible with derris.

FIELD TESTS.—Applications were made to control the Mexican bean beetle on early beans. The infestation was so light and irregular that the data were of no value. The untreated checks averaged only one larva to a plant, and egg masses were found on only three of the forty plants.

The tests were therefore repeated on the second generation, with applications on August 8 and 21, and counts of larvae surviving treatment on August 28 and 29. Results have been summarized in tables 6 and 7. For cube dusts, table 4 shows that Samples 54, 60, 63 and 69 produced higher mortalities than pyrophyllite at three of the four concentra-

tions used. Samples 61 and 67 were definitely inferior to pyrophyllite. Curves for the materials are shown in figure 5. In terms of dosage for equal control, at the 95 per cent level the following concentrations were required:

Pyrophyllite	.6%
54	.51
60	.51
63	.48
69	.40

Obviously 69 was the most effective material although the slope was somewhat flatter than the other materials.

Table 6.—Results of field tests of cube dusts to control the Mexican bean beetle.

Diluent	Per Cent Rotenone	No. Larvae Surviving	Per Cent Control
Pyrophyllite	0.125	169	71.9
	0.25	85	85.9
	0.5	45	92.5
	1.0	12	98.0
54	0.125	133	77.9
	0.25	133	77.9
	0.5	30	95.0
	1.0	9	98.5
60	0.125	180	70.1
	0.25	67	88.9
	0.5	38	93.7
	1.0	9	98.5
61	0.125	354	41.3
	0.25	255	57.5
	0.5	115	80.9
	1.0	33	94.5
63	0.125	274	54.5
	0.25	51	91.5
	0.5	27	95.5
	1.0	7	98.8
67	0.125	209	65.3
	0.25	150	75.1
	0.5	28	95.3
	1.0	20	96.7
69	0.125	60	90.0
	0.25	67	88.9
	0.5	17	97.1
	1.0	14	97.7
No treatment		603	

With cryolite it is difficult to fit curves to the scattered points (Fig. 6). All appear to be somewhat flatter than the pyrophyllite curve. At the 95 per cent level of control only 62 and 63 were more effective than pyrophyllite. The only obvious conclusion is that samples 62 and 63 appear to be slightly more effective than pyrophyllite. Their highly superior tenacity would account for this difference.

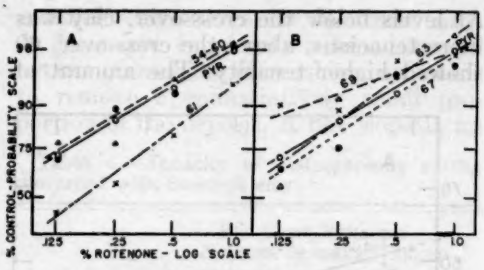

FIG. 5.—Dosage-response curves for control of Mexican bean beetles in the field. Diatomaceous diluents and pyrophyllite with cube root.

Late cabbage was dusted with cryolite combinations on August 29 and September 20 to control cabbage worms, chiefly loopers. The interval between treatments was long in order to accentuate differences in tenacity. Results were obtained by the scoring system, and reduced to per cennot damaged by dividing the total damt age score by the largest score possible and subtracting from 100. Results are summarized in table 8 and in figure 7. All three diatomaceous diluents were somewhat superior to pyrophyllite. The exceptionally high tenacity of sample 62 was not reflected in superior control, probably because of the high pH of the material. Sample 54 performed surprisingly well considering its low tenacity.

EASE OF DUSTING.—Notes were taken

Table 7.—Results of field tests of cryolite dusts to control the Mexican bean beetle.

Diluent	Per Cent Cryolite	Larvae Surviving	Per Cent Control
Pyrophyllite	6.25	232	53.6
	12.5	149	70.0
	25	66	86.8
	50	14	97.2
54	6.25	144	71.2
	12.5	84	83.2
25	25	17	96.4
	50	44	91.2
62	12.5	108	78.4
	25	16	96.8
	50	17	96.6
63	6.25	62	87.6
	12.5	31	93.8
	25	30	94.0
	50	27	94.6
67	6.25	125	75.0
	12.5	62	87.6
	25	40	92.0
	50	38	92.4
No treatment		499	

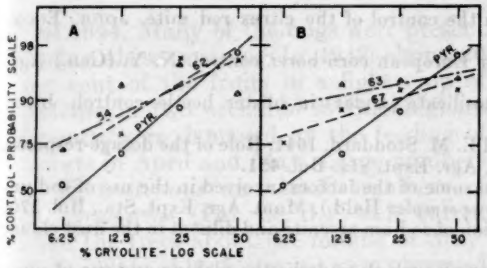

FIG. 6.—Dosage response curves for control of Mexican bean beetles in the field. Diatomaceous diluents and pyrophyllite with cryolite.

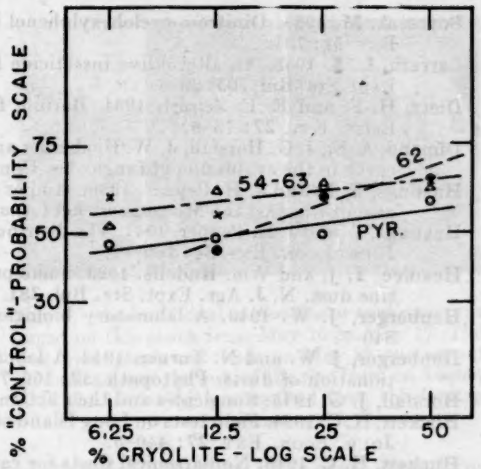

FIG. 7.—Dosage-response curves for prevention of damage by cabbage worms in the field. Diatomaceous diluents and pyrophyllite with cryolite.

on the ease with which the different diluents dusted and the type of dust cloud produced. Since there is only personal opinion and not scientific data, particularly as regards the dust cloud, these notes will not be presented. With the exception of the low concentrations all mixtures fed properly and could be applied easily except sample 54 with cryolite, which fed very poorly.

SUMMARY.—Fifteen laboratory samples of diatomaceous diluents were studied as diluents for pure ground derris root in the laboratory. Toxicity tests on *Aphis rumicis* showed that one (69) was superior to pyrophyllite, two others (54 and 63) approached pyrophyllite and a fourth (60) was somewhat less effective but produced a steeper dosage-response curve.

It was not possible to correlate toxicity with derris to the physical data available. However, materials of extremely fine particle size were not most effective as diluents for pure ground derris.

Tenacity studies showed that three types of curves were produced, flatter than, parallel with and steeper than the standard Bancroft clay. Two of the materials of high tenacity (60 and 63) were relatively effective as diluents for derris.

Materials were selected for field trials on the basis of effect on the toxicity and tenacity as determined in the laboratory.

Field tests on the Mexican bean beetle with cube showed that the materials performed in approximately the same order as in laboratory. The materials performed more in order of toxicity tests than of tenacity. The more effective materials performed relatively better in comparison with pyrophyllite in the field than in the laboratory.

In field tests of cryolite, materials of high tenacity performed well on both beans and cabbage, but less tenacious materials performed surprisingly well.—1-9-46.

Table 8.—Results of field tests of cryolite dusts to control cabbage worms.

DILUENT	PER CENT CRYOLITE	TOTAL SCORE	PER CENT NOT DAMAGED
Pyrophyllite	6.25	64	46.7
	12.5	62	48.4
	25	61	49.2
	50	50	58.4
54	6.25	69	42.5
	12.5	57	52.5
	25	44	63.4
	50	45	62.5
62	12.5	67	44.2
	25	47	60.9
	50	43	64.2
63	6.25	47	60.9
	12.5	53	55.9
	25	47	60.9
	50	43	64.2
No treatment		103	14.2

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Cat-Facing and Dimpling in Peaches

A. M. WOODSIDE, *Field Laboratory, Virginia Agricultural Experiment Station, Staunton*

Peach growers in Virginia have been suffering considerable losses from cat-facing and dimpling of the fruits caused by the feeding of various insects. Cat-facing consists of sunken areas, the surfaces of which are bare of pubescence, rough, and corky. Dimpling consists of sunken areas on which the pubescence persists. These types of injury are usually very unevenly distributed within an orchard as well as among different orchards. The fruits on trees around the edges of orchards and near fence rows, ditches, and waste ground are usually more severely damaged than fruits in other parts of orchards. Generally cat-facing and dimpling may be expected to appear in the same orchards and in the same parts of orchards year after year.

CAUSES OF CAT-FACING AND DIMPLING.—In 1941 a large percentage of the fruits in two peach orchards in Rockingham County were scarred by the feeding of unknown insects. In the spring of 1942 trees in these orchards were jarred and large numbers of *Euschistus servus* (Say)[1] and a few *E. tristigmus* (Say) were collected. Cat-facing was again common on the fruits and was also common in 1943

[1] The determinations of these bugs were made by Dr. R. I. Sailer of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine. Dr. Sailer is of the opinion that the bugs discussed in this paper under the name of *Euschistus servus* were a hybrid population of the two subspecies *E. servus servus* (Say) and *E. servus euschistoides* (Vollenhaven).

and 1944. Many of the bugs were present during these seasons. In 1943 about 20 per cent of the fruits in a light crop of peaches in two orchards in Buckingham County were damaged by the feeding of insects in April and May. Large numbers of *E. tristigmus* and small numbers of *E. variolarius* (Pal. de B.)[2] were jarred from the trees about the middle of May. Individuals of both species were observed in the act of feeding on peach fruits on the trees at this time.

The plum curculio, the tarnished plant bug, and the green stinkbug may also cause cat-facing or dimpling of peaches. It is usually impossible to determine the cause of the injuries after they have healed. It is well known that plum curculio causes scarring of peaches. Scars resulting from the feeding of the plum curculio are often smaller than those produced by the other insects. Bobb[3] found that the tarnished plant bug produced cat-facing on peaches when caged on young fruits and observed that such scars were common on peaches in orchards where these bugs had been present in large numbers. In 1939 the author found very heavy damage to the peaches in a part of an Amherst County orchard caused by the feeding of large numbers of the green stinkbug, *Acrosternum hilare* (Say). These injuries were of the dimpling type resulting from the shrinkage of the tissues injured by the feeding of the bugs.

METHODS OF STUDY.—In the spring of 1944 overwintered insects entering peach orchards were collected by jarring the trees. Individuals of each species of heteropterous insect thus collected were caged on peach branches with fruit. Each fruit used for this purpose was first examined to ascertain that it was free of signs of previous feeding by insects. Cheesecloth bags about 6 by 10 inches in size were used as cages. Examinations were made of the cages at intervals of 3 or 4 days. At first they were moved to new locations at each examination, but later in the season they were allowed to remain much longer over each fruit. In the spring each overwintered stinkbug was placed in a separate cage. When first-brood adults of these bugs were obtained a pair was placed in each cage. The first bugs were caged on peaches on April 18 before all of the petals had fallen and the work was continued until the fruit was harvested.

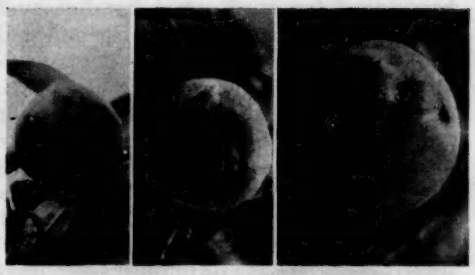

FIG. 1.—An individual of *Euschistus tristigmus* was caged on this peach from May 10 to May 17. The first photograph was made on May 17, the second on June 28, and the last, of the ripe fruit, on August 9. Slight puckering has resulted from the feeding injuries.

EFFECTS ON PEACHES OF FEEDING BY BUGS.—The first peaches on which bugs were caged soon dropped. Peach fruits which were attacked by brown stinkbugs before the shuck had been shed dropped within 24 hours after being fed upon. Fruits of less than three-eighths inch in diameter dropped within 3 days. Fruits between three-eighths inch and one-half inch in diameter sometimes survived the feeding of these bugs, and fruits of greater than one-half inch in diameter often sur-

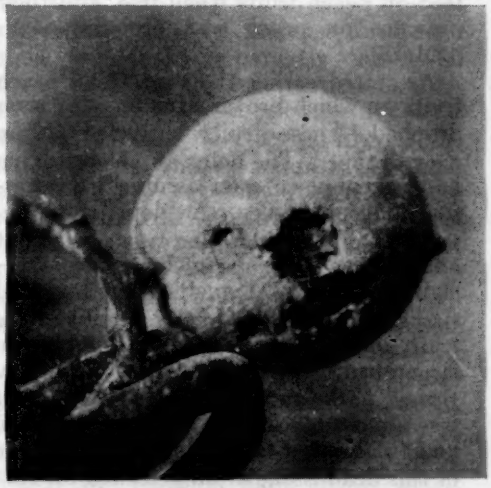

FIG. 2.—An individual of *Thyanta custator* was caged on this peach from May 8 to May 12, and the photograph was made on August 9. The scar was produced by the coalescence of two or more feeding scars, and resembles scars produced by the feeding of *Euschistus* spp.

[2] The name of "brown stinkbugs" is suggested for the species of *Euschistus* which are brown in color. These bugs have no recognized common names, and the use of this name will obviate the necessity of repeated use of the generic name.

[3] Unpublished notes.

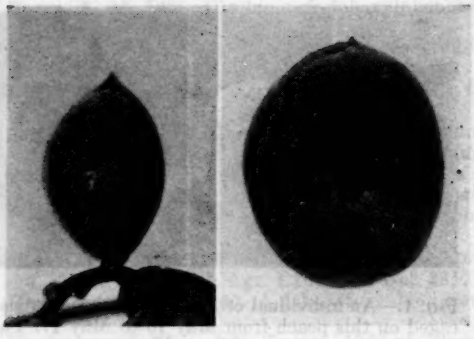

FIG. 3.—An individual of *Euschistus variolarius* was caged on this peach from April 27 to May 4. The photograph at the left was made on May 25, the other on August 21. Considerable puckering resulted from the deep injury.

vived. Had the bugs been moved after only 1 day of feeding on each fruit it is probable that the dropping would have been much less severe.

The following stinkbugs were observed to feed upon peaches in the orchard, and all of them caused cat-facing on peaches on which they were caged: *Thyanta custator* (Say), *Euschistus servus* (Say), *E. tristigmus* (Say), *E. variolarius* (Pal. de B.) and *Acrosternum hilare* (Say). Two species of coreids, *Anasa tristis* (DeG.) and *Chariesterus antennator* (Fab.), caused cat-facing when caged on peach fruits, but neither of these species was observed to feed on peach fruits when free, and their presence on peach was probably accidental.

As stated earlier the very small peach fruits on which brown stinkbugs fed soon dropped. These fruits shriveled before they dropped. The point at which feeding had taken place soon assumed a water-soaked appearance. A depression developed as the underlying tissue dried out and shrank. In fruits of less than three-eighths inch in diameter the lacerated tissue included most of the interior of the fruit, and such fruits dropped quickly. On larger fruits the surface over the injury turned dark, and in two or three days it was almost black. The skin cracked open and the injured tissue sloughed off. Some of this dead tissue often persisted for several weeks. The surface exposed by the sloughing off of the dead tissue was rough, and it became corky as it healed (Figs. 1 and 2). The feeding of brown stinkbugs on peach fruits from one-half inch to 1 inch

FIG. 4.—A green stinkbug, *Acrosternum hilare*, was caged on this peach from June 1 to June 8. This photograph of the ripe fruit, made on August 9, shows the dark sunken spots or dimples that resulted from the feeding of the bug.

in diameter usually produced typical cat-facing such as this. The injured regions of the fruits often grew less rapidly than the surrounding area, resulting in distortion (Fig. 3). This was particularly true when the injury was deep or relatively large. There was a tendency for cracks to develop around the scars as such fruits ripened.

When the fruits attacked were an inch or more in diameter the injured tissue usually did not slough off. The flesh dried out and became corky, resulting in a depression or dimple (Fig. 4). The development of a dimple might be delayed in wet weather by the formation of a pocket of gum, some of which was often exuded. Dimpling in peaches is characteristic of the feeding injuries of the green stinkbug, which seldom attacks peaches in Virginia before July. Dimpling was produced in the cages by the feeding of brown stinkbugs in June and July. In the free state these bugs usually leave the peach trees before the fruits are large enough for dimpling to be produced.

The young of each of the three species of *Euschistus* were reared in the cages on peach, and they fed readily on the fruits. Slight dimples were formed on the fruits as a result of their feeding injuries. These dimples would have been inconspicuous

had they not been so numerous. The fruits in the cages, however, were so thickly covered by them that they were very noticeable, particularly when the fruits ripened and the dimples remained green. This type of injury was seldom found in the orchard. Even on trees where injuries by the adult brown stinkbugs were very common it was difficult to find evidence of feeding by nymphs. Small numbers of nymphs of the first and second instars were often jarred from peach trees, but older nymphs were never found on peach.

SUMMARY.—Peach growers in Virginia have suffered losses from cat-facing and dimpling of fruits caused by the feeding of insects. Cat-facing results from the attacks of insects when the fruits are small, and may be caused by the plum curculio and the tarnished plant bug. Most cat-facing in Virginia orchards seems to be caused by three species of stinkbugs of the genus *Euschistus*. The overwintered adults enter the orchards in April and feed on the young fruits. Dimpling is usually caused by the green stinkbug in midsummer.—1-9-46.

Life History Studies of *Euschistus servus* and *E. tristigmus*

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In the spring of 1944 overwintered adults of *Euschistus servus* (Say), *E. tristigmus* (Say), and *E. variolarius* (Pal. de B.)[1] were caged on peach branches with fruit. Females of each of these species oviposited in the cages, and notes were made on the development of the young in these cages. In the spring and summer of 1945 a study of the life histories of *E. servus* and *E. tristigmus* was made in the insectary at Staunton. Overwintered pairs of the bugs were placed in battery jars over moist sand. Each battery jar was furnished with a twig of peach with fresh leaves and a firm ripe tomato as food. The cages were examined daily, and the food was renewed when necessary. When eggs were deposited they were removed and placed in small vials until they hatched. Upon hatching the young were transferred to battery jars, where they were reared, except for a few individuals of each species, which were reared separately in jelly jars for the purpose of determining the length of the various nymphal stages. The nymphs were furnished with peach foliage and ripe tomatoes as food.

LIFE HISTORY DATA.—The eggs of each of the three species of *Euschistus* were deposited in clusters on the lower surfaces of the leaves. These clusters often contained seven eggs or a multiple of seven, arranged in alternate rows of four and three eggs each. This was almost always true of the eggs deposited in the cages on the trees, but the number and arrangement of the eggs deposited in the insectary were not consistent. On a few occasions in the insectary eggs were deposited on the sand in the bottom of a jar or on the cheesecloth cover.

In 1944 the first eggs of *Euschistus servus* were deposited in the cages about May 10, and females of this species continued to deposit eggs until after June 15. After hatching the young bugs remained clustered on the eggs until after their first molt, apparently taking no food during the first instar. After molting they scattered over the foliage and fruit within the cage, feeding readily on the fruit. The nymphs confined to peach grew slowly, requiring more than 2 months to reach maturity. The bugs reared entirely on peach were smaller at maturity than individuals of the same species collected in the field. Peach is evidently not a satisfactory host for this species throughout its development.

Euschistus servus produced a second generation. First-brood females deposited eggs in the cages. These eggs hatched and the nymphs fed on the ripening fruit. When the peaches were picked about August 10, part of these nymphs were removed to the insectary where they were placed in battery jars and given access to fresh peach foliage and ripe peaches. All of these nymphs died before

[1] The determinations of these bugs were made by Dr. R. I. Sailer of the Division of Insect Identification, Bureau of Entomology and Plant Quarantine. Dr. Sailer is of the opinion that the bugs discussed as *Euschistus servus* in this paper were a hybrid population of the two subspecies *E. servus servus* (Say) and *E. servus euschistoides* (Vollenhaven).

September 15, the younger ones perishing first. The remainder of the nymphs were left in the cages on the peach trees, but all of them died before September 7.

In 1945 the first eggs of *Euschistus servus* were deposited in the insectary on April 26. Eggs were deposited by the overwintered adults from this date until July 18. Two females deposited a total of 196 eggs. The number of eggs per cluster varied from 1 to 28, the average being 16.3. The length of the incubation period and of each of the nymphal stages is given in table 1. The mortality of the nymphs was heavy.

Table 1.—Length of the pre imaginal stages of *E. servus*.

Stages	Length in Days		
	Max.	Min.	Mean
First generation			
Incubation	25	5	9.3
1st nymphal	7	4	5.3
2nd nymphal	13	7	9.3
3rd nymphal	17	4	10.3
4th nymphal	21	8	13.0
5th nymphal	20	7	13.6
Total nymphal period	63	41	51.5
Second generation			
Incubation	12	6	8.1
1st nymphal	6	5	5.8
2nd nymphal	11	6	7.6
3rd nymphal	14	5	7.8
4th nymphal	15	9	11.6
5th nymphal	27	17	22.1
Total nymphal period	66	48	54.9

Five first-brood females deposited 524 eggs between August 2 and September 25. The largest number of eggs deposited by one female was 122. The number of eggs per cluster varied from 1 to 28, and the average was 12.5. In table 1 are given the length of the incubation period and of the nymphal stages. Many of the individuals did not reach maturity; otherwise the maximum and average lengths of the various periods would have been longer.

The life history of *Euschistus tristigmus* was very similar to that of *E. servus*. In 1944 the first eggs were deposited in the cages on May 5, and they hatched about May 18. *E. tristigmus* females continued to deposit eggs until about the last of June. The behavior and development of the nymphs was similar to that of the *E. servus* nymphs, but the nymphal period was a little shorter. The adults reared on peach were a little smaller than those collected in the field. *E. tristigmus* also produced a second generation.

In 1945 the first eggs of *Euschistus tristigmus* were deposited in the insectary on April 18. Only a few first-brood eggs were obtained, all of which were deposited before May 10. The incubation period varied from 14 to 20 days. The nymphs passed through five instars, and their behavior and development were similar to that of the *E. servus* nymphs. The total nymphal period varied from 43 to 62 days, with an average of 48 days.

Three first-brood females of *Euschistus tristigmus* deposited 330 eggs, 193 of these being deposited by one female. The number of eggs per cluster varied from 3 to 28, with an average of 15.7. In table 2

Table 2.—Length of the pre-imaginal stages of the second brood of *E. tristigmus*.

Stage	Length in Days		
	Max.	Min.	Mean
Incubation	9	7	7.5
1st nymphal	6	5	5.8
2nd nymphal	18	10	14.1
3rd nymphal	17	10	13.4
4th nymphal	9	6	6.7
5th nymphal	15	9	13.5
Total nymphal period	57	48	53.4

are given the lengths of the incubation period and of the nymphal stages of the second brood of *E. tristigmus*.

Two females of *Euschistus variolarius* deposited eggs in the cages on peach trees in 1944, and the young were reared in these cages. The nymphal period of *E. variolarius* was longer than that of either *E. servus* or *E. tristigmus*. *E. variolarius* did not produce a second generation in the cages.

Collection of *Euschistus* bugs by the jarring of peach trees shows that *E. servus* and *E. tristigmus* are often fairly common in Virginia peach orchards when the petals are falling and for several weeks afterward. Most of them leave the peach trees by June 1. Some eggs are deposited on peach by both species. Nymphs larger than second-instar have not been collected from peach.

Attempts to collect these bugs from weeds and cover crops in peach orchards and from crop plants in fields near infested orchards have given meager results. Very

few of them have been found on any plant except common mullein, *Verbascum thapsus* L. Considerable numbers of all stages of *E. servus*, *E. tristigmus*, and *E. variolarius* have been found on this plant wherever collections have been made. Nymphs of *E. servus* have often been found on tomato, but never in large numbers. A few *E. servus* nymphs have been collected from snap beans. *E. variolarius* nymphs and adults have been found in large numbers on corn plants.

SUMMARY.—Life histories of the stinkbugs *Euschistus servus* and *E. tristigmus* were studied in cages on peach trees and in the insectary, and some observations were made on the life history of *E. variolarius* in the orchard. *E. servus* and *E. tristigmus* produced two generations per year, but *E. variolarius* seems to have but one generation. All three species were reared on peach, but it is not an entirely satisfactory host. Many of the bugs were collected from common mullein.—1-9-46.

Life History and Habits of *Strigoderma arboricola*

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During the course of a 4-year study on peanut leaf-spot control in Eastern Virginia, Miller (1943) observed damage to peanut pods caused by white grubs. The damage was first noticed in 1938 but it was not until the fall of 1940 that the insect responsible for the damage was identified as *Strigoderma arboricola* (Fab.). Miller (1943) has stated that as many as 35 grubs were found under a single hill of peanuts, and that losses may amount to 85 per cent in some peanut fields with a total loss in parts of infested fields.

The study reported herein was conducted during 1944 and 1945 at a field laboratory located at Holland, Virginia, in the peanut-growing area of Virginia. In the fall of both years rather extensive surveys were made during the period that peanuts were being dug, in an attempt to evaluate the damage to peanut pods from grubs and other subterranean insects. A total of 50 fields, located in four different counties, were examined in this fashion in 1944. Conspicuous injury from grubs was observed in only 3 of the 50 fields examined and in those fields it occurred in only limited areas. In 1945 a total of 44 peanut fields, located in four different counties, were examined at time of digging. In none of the fields examined was it estimated that the injury to the peanut pods from grubs would exceed 3 or 4 per cent.

Preliminary data on the life cycle of *Strigoderma arboricola* in Kansas has been reported by Hayes (1921). The incubation period of 28 eggs was found to vary between 10 and 14 days with an average of 12.2 days. Four larvae reared to maturity required an average of 321.7 days for the larval period, 6.2 days for the prepupal period, and 12.7 days for the pupal period. The adults were found to emerge during May, June, and July and the eggs were deposited in June and July.

Further notes on the life history of *Strigoderma arboricola* have been reported by Hoffmann (1936) in Minnesota. The grubs were reared in a basement room at a temperature of approximately 23° C with the following results: the prepupal and pupal periods required 6 and 13 days, respectively; the longevity of 21 beetles varied from 11 to 31 days with a mean of 18.8 days; the incubation period of 36 eggs varied from 11 to 25 days with a mean of 17 days; and the preoviposition period required 11 days.

The adults of *Strigoderma arboricola* have been reported by different authors as collected from the blossoms of a rather large number of plants. Hart & Gleason (1907, p. 244) have reported the adults on the blossoms of clover, rose, *Opuntia humifusa*, and *Monarda punctata*. Blatchley (1910), has recorded the beetles as occurring most commonly on the blossoms of wild rose, blackberry, and the water willow, *Dianthera americana* L. Notes recorded by Vestal (1913, p. 45) report the adults as being excessively abundant in late June on cactus, wild rose, red clover, timothy, elderberry, dewberry, dog fennel, *Verbena stricta*, wild parsnip, *Monarda punctata*, *Plantago*, *Saponaria*

[1] Acknowledgment is made to Miss Sara Rawles for laboratory assistance during part of the 1945 season.

sp., *Tephrosia*, and *Erigeron*. Vestal also found the adults to be abundant on prairie plants and in bunch grasses but not at all common in the forests. Hayes (1921) considered the blossoms of wild and cultivated rose plants as being the preferred food of the adults in Kansas. Hoffmann (1936) collected the adults in Minnesota from the flowers of both wild and cultivated roses, water-lily, *Phleum pratense* L., *Achillea millefolium* L., *Amorpha canescens* Pursh, fireweed, and peony. Miller (1943), working in Eastern Virginia, found that the adults inflict their greatest damage to the blossoms of roses, although they were observed to attack other ornamentals as well as the foliage and blossoms of peanuts. Hyslop, of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, made the following statement[1] in 1942: "In the records of the Insect Pest Survey we have reports of damage by *Strigoderma arboricola* F. to blossoms of coreopsis, muskmelon, cucumbers, iris, cotton, lilies, snap beans, roses, cowpeas, corn, hollyhocks, and smartweed."

METHODS.—Most of the information on the life history of *Strigoderma arboricola* was obtained by rearing the insect in a small building that had more than one-half of the area on three sides covered with screen. For obtaining eggs, and information on adult longevity, preoviposition, and number of eggs deposited, the adults were reared either in 12 by 12 by 12 inch screen cages or in glass battery jars of approximately 1-gallon capacity. The screen cages fitted tightly over trays containing several inches of soil, and about the same depth of soil was placed in the battery jars. Fresh food, consisting of the blossoms of various flowers, was provided at all times and the soil was kept moist. At 2-day intervals the soil was passed through an 8-mesh screen for removal of eggs and observations on adult activities.

The eggs were incubated and the resulting larvae were reared in 2-ounce metal boxes that were kept on shelves in the screened laboratory. From 5 to 7 eggs were placed in each box in depressions made in the tightly packed soil. Observations were made once or twice each day and the larvae were removed immediately upon hatching. A single larva was reared in each box. As a source of food a small amount of wheat bran and 5 or 6 grains of wheat were mixed with the soil. Fresh food and soil were substituted as needed.

For prepupal and pupal observations the overwintering larvae were kept singly in 2-ounce boxes in the screened laboratory. In order to facilitate observations, when the larvae become prepupae they were placed in depressions in the soil resembling pupal cells.

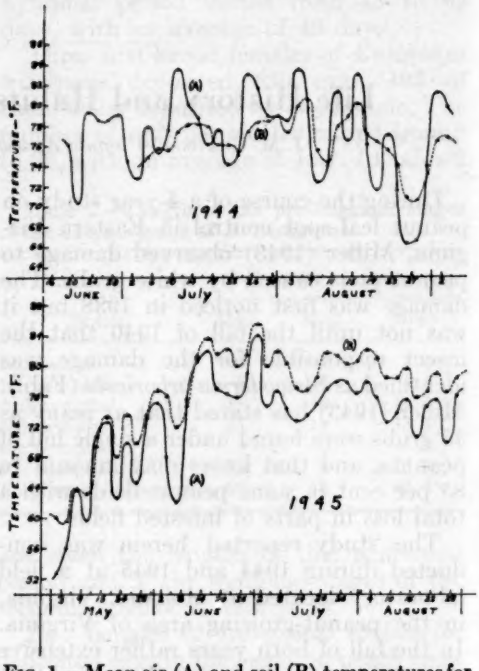

FIG. 1.—Mean air (A) and soil (B) temperatures for 1944 and 1945 at Holland, Virginia.

Thermographic records were obtained of the temperatures in the screened laboratory and at a depth of 6 inches in the soil. The mean temperatures occurring during the principal periods of growth and activity of *Strigoderma arboricola* under both of these conditions are shown in figure 1.

EGG.—In 1944 eggs were deposited by *Strigoderma arboricola* in the screened laboratory from June 10 to June 25, the peak of eggs deposition being between June 16 and June 24. In 1945 eggs were deposited from May 30 to June 26 with the principal period of egg deposition extending from June 1 to June 19. The incubation period of the eggs is shown in table 1.

[1] Private communication.

Table 1.—Lengths of the various immature stages of *Strigoderma arboricola*. Holland, Virginia.

Stage	Year	Number Observed	Length of Stages (Days)		
			Maximum	Minimum	Mean
Egg	1944	182	19	8	13.6
	1945	707	21	8	13.4
First-instar larva	1944	168	25	13	16.2
	1945	140	30	12	16.6
Second-instar larva	1944	168	21	12	15.1
	1945	125	36	10	17.5
Third-instar larva	1944 to 1945	63	292	238	257.3
Prepupa	1945	86	20	5	11.4
Pupa	1944	9	13	9	11.9
	1945	103	32	15	24.9

The freshly deposited eggs of *Strigoderma aboricola* are white in color, round in minor axis, and oblong in major axis. As time of hatching approaches they become more spherical in shape. The major axes of 52 eggs from 1 to 2 days in age varied from 1.27 mm. to 1.59 mm. with a mean of 1.41 mm., and the minor axes varied from 0.95 mm. to 1.27 mm. with a mean of 1.07 mm. Measurements on 51 eggs from 12 to 13 days in age were as follows: major axes from 1.64 mm. to 2.05 mm. with a mean of 1.86 mm., and minor axes from 1.55 mm. to 1.73 mm. with a mean of 1.63 mm.

LARVAE.—In 1944 larvae were reared both in the screened laboratory and in a box located at a depth of approximately 6 inches in the soil. However, the resulting rates of development were so nearly similar that the data obtained were combined and in 1945 all of the larvae were reared in the screened laboratory. The results are shown in table 1.

PREPUPA AND PUPA.—In the spring of 1944 no information was obtained on the prepupal period of *Strigoderma arboricola*, but in the spring of 1945 most of the larvae in the screened laboratory entered the prepupal period between April 8 and April 20. Observations made from nearby field collections indicated the beginning of the prepupal period to be almost a week later in the field.

Data were obtained in the spring of 1944 and of 1945 regarding the pupal stage of *Strigoderma arboricola*. Fifteen grubs collected from the field in 1944 and brought into the screened laboratory for observation entered the pupal period between May 15 and Mary 24. In the spring of 1945 most of the grubs under observation in the screened laboratory entered the pupal stage between April 16 and April 30, although a few did not do so until as late as the latter part of May. The time of entering the pupal period in the field was probably several days to a week later.

ADULT.—In 1944 the first adults of *Strigoderma arboricola* appeared on May 28 in the screened laboratory and the first observation of an adult in the field was on June 1. Adults were present in the field from this time until the end of the first week in July with the maximum population occurring between June 6 and June 15. In 1945 adults of *Strigoderma arboricola* appeared as early as May 16 in the screened laboratory, yet the first observation of an adult in the field was on June 1. Adults were observed in the field throughout the month of June with the maximum population occurring between June 9 and June 20.

The length of the adult stage for 41 females of *Strigoderma arboricola* reared in 16 different cages in the screened laboratory varied from approximately 3 days to 30 days with a mean of 17.0 days. The adult longevity of 51 males similarly reared varied from approximately 3 days to 27 days with a mean of 16.7 days.

In determining the preoviposition period of the adults of *Strigoderma arboricola* from 1 to 6 newly emerged females, with a corresponding number of males, were reared in each of fifteen different cages. The length of time before eggs were obtained varied from 7 to 16 days with a mean of 12.5 days.

HABITS.[1]—The blossoms of various wild and cultivated plants apparently constitute the principal food of the adults of *Strigoderma arboricola*. More adults were collected by the author from roses (garden types, both bush and climbing) than any other species of plants, and they appeared to feed more voraciously on the blossoms of roses than those of most plants. Other plants on which the adults were commonly collected were perennial peas, *Lathyrus latifolius*, hairy vetch, *Vicia villosa*, hollyhocks, *Althaea rosea*, elder, *Sambucus canadensis*, honeysuckle, *Lonicera japonica*, and white-topped aster,

[1] Acknowledgment is made to Prof. A. B. Massey, Department of Biology, Virginia Polytechnic Institute, for the identification of all plants.

Sericocarpus linifolius. The adults appeared to prefer the white or light-colored blossoms to those of darker colors. After the fruits of blackberries, *Rubus* spp., ripened large numbers of adults were found in clusters on berries that had become overripe.

Some plants that were in blossom during the periods that the adults of *Strigoderma arboricola* were in flight but on which no adults were ever observed feeding were yarrow, *Achillea millefolium*, butterfly weed, *Asclepias tuberosa*, fleabane, *Erigeron ramosus*, wild indigo, *Baptisia tinctoria*, and fragrant goldenrod, *Solidago minor*.

The eggs of *Strigoderma arboricola* are deposited singly in the soil. The number of eggs deposited was determined by rearing from 1 to 5 females, with a corresponding number of males, in each of fifteen cages and keeping a record of oviposition. A total of 36 females reared in this fashion deposited a total of 947 eggs, with a mean of 26.3 eggs per female. The largest number of eggs deposited by any of the 4 females reared singly was 44 eggs.

Attempts to determine the depths in the soil that the eggs of *Strigoderma arboricola* are normally deposited were not very successful. However, the author is of the opinion that the eggs are usually deposited at depths of from 2 to 3 inches.

The grubs of *Strigoderma arboricola* apparently feed on the underground parts of various cultivated crops and grasses. In the fall of 1944 grubs of this species were collected from the soil in fields in which peanuts, corn, and corn interplanted with soybeans had been growing. In the spring of 1945 grubs of this species were collected behind the plow from sod land, cultivated land that had been allowed to grow up in weeds, and from fields in which peanuts, corn, corn interplanted with soybeans, and cotton had been growing the previous season.

Grubs of *Strigoderma arboricola* were found more often in the darker soils containing finer particles and more organic matter than in the coarser, lighter soils with less organic matter. However, an ever greater difference in population was observed between low, poorly drained soils and those that were well drained. The most common location for grubs, especially in large numbers, was either in low areas or in areas that had a tendency to remain moist at all times.

Strigoderma arboricola passes the winter as a third-instar larva in the soil. The depths of hibernation of 14 grubs from two different fields in the late fall of 1944 varied from 5.5 to 9.5 inches with a mean of 7.7 inches. In the early fall of 1945 grubs were allowed to enter the soil at two different locations and examinations made for the depths of hibernation on December 8. At one location 16 grubs were recovered at depths ranging from 5.0 inches to 11.0 inches with a mean of 7.8 inches. Most of the grubs at the second location were found at depths between 2.0 inches and 3.5 inches; however the soil had a tendency to remain excessively moist which probably caused them to hibernate at abnormally shallow depths.

DISCUSSION.—The variations in lengths of the different life stages of *Strigoderma arboricola* as they occur in Kansas (Hayes 1921) or Minnesota (Hoffmann 1936) in contrast to Virginia, and the variations in data obtained for 1944 and 1945 in Virginia, can be accounted for by differences in temperature. In the spring of 1945 the weather was unseasonably warm in Eastern Virginia during the last half of March and the first part of April, resulting in most of the grubs of *Strigoderma arboricola* entering the prepupal and pupal stages from 3 to 4 weeks earlier than in 1944. The warm period was followed by normal to subnormal temperatures that slowed down development to maturity. Consequently, the length of time normally spent in the third larval instar was reduced, whereas the duration of the prepupal and pupal periods were longer than usual. In most years the overwintering larvae of *Strigoderma arboricola* probably enter the prepual stage during the first or second week in May, the pupal stage during the second or third week in May, and become adults during the latter part of May.

The mean soil temperatures during the year 1945 were consistently higher than the corresponding air temperatures (Figure 1). This can perhaps be attributed to the type of vegetation under which the former were taken. In 1945 the soil temperatures were recorded under sod land that was very closely grazed, whereas in the previous year they were taken under

sod land containing a moderate growth of vegetation.

Strigoderma arboricola is not host specific in either the adult or the larval stage. As previously indicated, the adults have been observed feeding on the blossoms of a wide variety of plants, and the list of host plants perhaps would be even longer if more exhaustive observations were made. The sluggish nature of the adults, and the rather short period in which they are present in the field, probably influence the tendency to feed on the blossoms of whatever host plants are available. The larvae apparently feed on the underground parts of corn, corn interplanted with soybeans, peanuts, and cotton, which constitute the principal agricultural crops grown in the peanut-producing area of Virginia. They have also been collected from sod land.

Observations during the seasons 1944 and 1945 indicate the grubs of *Strigoderma arboricola*, or any other species of grubs, to be minor insect pests of peanut pods in the soil. The author in no case observed injury that would even approach being equal to that reported by Miller (1943). It is possible that a grub population might occasionally be obtained which would be capable of causing a total loss of peanut pods, although such an occurrence is probably rare.

SUMMARY.—The results of a 2-year study on the economic importance, life history, and habits of *Strigoderma arboricola* in Eastern Virginia are reported. Surveys of peanut fields at time of digging revealed only minor injury to the pods attributable to the grubs of *Strigoderma arboricola* or any other species of grubs.

Strigoderma arboricola required one year for a single generation. The winter was passed as a third-instar larva in the soil at a depth of approximately 7.7 inches. The number of days required for the various life stages during the years 1944 and 1945, respectively, were as follows: egg, 8 to 19 with a mean of 13.6 and 8 to 21 with a mean of 13.4; first-instar larva, 13 to 25 with a mean of 16.2 and 12 to 30 with a mean of 16.6; second-instar larva, 12 to 21 with a mean of 15.1 and 10 to 36 with a mean of 17.5; third-instar larva (1944–45), 238 to 292 with a mean of 257.3; prepupa (1945), 5 to 20 with a mean of 11.4; and pupa, 9 to 13 with a mean of 11.9 and 15 to 32 with a mean of 24.9.

The mean adult longevity was 17 days for the females and 16.7 days for the males. The mean preoviposition period was 12.5 days, and a mean of 26.3 eggs per female were deposited.

Neither the adults nor the grubs of *Strigoderma arboricola* were host specific. The adults were collected from the blossoms of a number of different plants, and the grubs were collected from the soil under all of the principal agricultural crops grown in the peanut-producing area of Virginia.

The dates of adult emergence, egg deposition, and time of entering prepupal and pupal stages are discussed. Measurements of major and minor axes of eggs 1 or 2 days and 12 or 13 days in age are stated.

The soil and air temperatures occurring during the principal periods of growth of *Strigoderma arboricola* are shown graphically.

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The European Chafer *Amphimallon majalis* and Its Control in Lawns[1]

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The European chafer *Amphimallon majalis* Raz., in its larval stage, feeds upon the roots of various species of grass, among other plants, and causes severe damage to turf in lawns, parks, golf courses, and cemeteries (Gambrell *et al.* 1942). In addition, injury has been observed on the roots of a number of species of coniferous, lining-out nursery stock (Gambrell 1943) as well as upon grass in pastures, legumes, oats and corn (Schwardt & Whitcomb 1943). Both *A. majalis* and *A. solstitialis*, a closely related European form, are reported as being injurious to turf in Europe (Regnier 1935, 1939). In fact, Regnier considers *A. majalis* as one of the most serious pests of grass in France and reports severe damage to turf, parks and golf courses, particularly along the Seine River in the vicinity of Rouen and in the coastal zone of Calvados. Aullo (1929) reports injury to the foliage of conifers in Spain by the adults of *A. majalis* and *A. pini*. In the United States injury to foliage by the adults of the former species has been negligible and is not an important consideration in control.

The first known evidence of damage to turf in this country was observed on a few lawns in the village of Newark, N. Y. during the spring of 1940 (Gambrell *et al.* 1942). This damage was first called to our attention by Mr. B. R. Blanch and Mr. H. P. Breitfeld, Horticultural Inspectors, Bureau of Plant Industry, New York Department of Agriculture and Markets. Digging records made in two lawns on April 27, 1940, showed a maximum of 27 grubs and an average of 8.8 grubs per square foot. An adult reared from this material which was deposited in the U. S. National Museum aided those workers in the determination of the insect to species (Böving 1942). In nearby sections numerous lawns as well as turf in parks, cemeteries and a golf course showed serious damage by the fall of 1941. The area included in the most heavily infested territory has become extended in a more or less circular fashion from the point where it was first observed so that at present the zone of serious damage occurs in localized sections over an area of about 10 square miles. On the basis of surveys made during the period of adult activity in 1945 the present known distribution occupies an area of approximately 150 square miles.

Habits and Infestation.—The extent and seriousness of damage to lawns in 1941 clearly indicated a need for information on the biology and control of this pest. Investigations along these lines were initiated in 1942 in cooperation with the Department of Entomology, New York State College of Agriculture; Bureau of Plant Industry, New York State Department of Agriculture and Markets (Gambrell & Buchholz 1942); and the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. Early observations revealed that during the fall and early spring months red-winged blackbirds, bronzed grackles, starlings, robins, song sparrows, crows and skunks consume large numbers of the grubs during the period when they are present near the surface of the soil and when turf injury is quite evident; also song sparrows, chipping sparrows, robins, toads and cats, feed upon the adults as they emerge from the soil in the evening and fly to the trees. The feeding activity of these animals doubtless reduces the population but thus far does not appear to have been sufficient to prevent damage. Turf injury is very similar in appearance to that caused by the larvae of such pests as the Japanese beetle, the rose chafer and various species of white grubs (Fig. 1). Generally speaking, evidence of injury is rather spotty in any given locality. Usually it is limited to open sunny areas but it may also occur in turf immediately under trees from which mated pairs of beetles fall to the ground. Turf growing on well drained locations and sloping areas of light sandy to heavy and gravelly loam soils of the Madeland, Ontario and Palmyra series usually show the greatest amount of damage. The amount and severity of visible injury to

[1] Journal Paper No. 663, New York State Agricultural Experiment Station, Geneva, N. Y.

turf is apparently influenced by both temperature and rainfall during the period when the grubs are most active.

The emergence period extends from about the second week in June until around the first of August. Maximum daily emergence occurs during late June and early July. During this period the adults come out of the soil each evening just after sunset, fly to trees, shrubs, chimneys, poles or other suitable objects where they come to rest, copulate, and remain during the night. Just before dawn these beetles resume activity and fly back to the ground where they dig into the soil or turf and where oviposition occurs. Grubs appear in numbers by mid-July and remain within a few inches of the surface, except during periods of hot dry weather and during the winter when the ground is frozen, until they reach maturity about the middle of May of the following spring. Regnier (1939) observes that "the duration of the life cycle in Normandy is 2 years but takes place during parts of 3 years," whereas records obtained by the writer in the United States definitely indicate the insect has a 1-year life cycle under average conditions. However, instances have been observed where a small percentage of larvae, possibly due to lack of food, unusual temperatures or heavy soil type, carry over to the second year before emerging as adults.

1942 EXPERIMENTS FOR CONTROL OF LARVAE.—Eighteen plots containing one-twentieth acre each were treated with lead arsenate in either spray or dry form at rates of 250, 500 and 1000 pounds per acre. Applications were made between July 8 and July 15th, respectively, during the period of adult emergence, oviposition, and egg hatching. One plot which was treated at the rate of 1000 pounds per acre during July received an additional treatment of 500 pounds per acre on September 8th, thus making a total dosage of 1500 pounds per acre. In dry form one part of lead arsenate was mixed with two parts by weight of screened fine sandy loam soil and applied with a hand fertilizer distributor. Lead arsenate sprays were applied at 300 pounds pressure with a power sprayer, incorporating the insecticide in the spray tank at the rate of 8 ounces per gallon of water. Following application the arsenical was "washed in" with the same machinery using water at a minimum of about 1500 gallons per acre. In addition a half-acre of turf at the N. Y. Telephone Co. and 4 acres of turf surrounding the club house of the Newark Country Club were treated at the rate of 500 pounds per acre during late July and early August, at which time first and second instar larvae were present. The weather was hot and dry during most of July, August and early September with the result that many of the larvae were

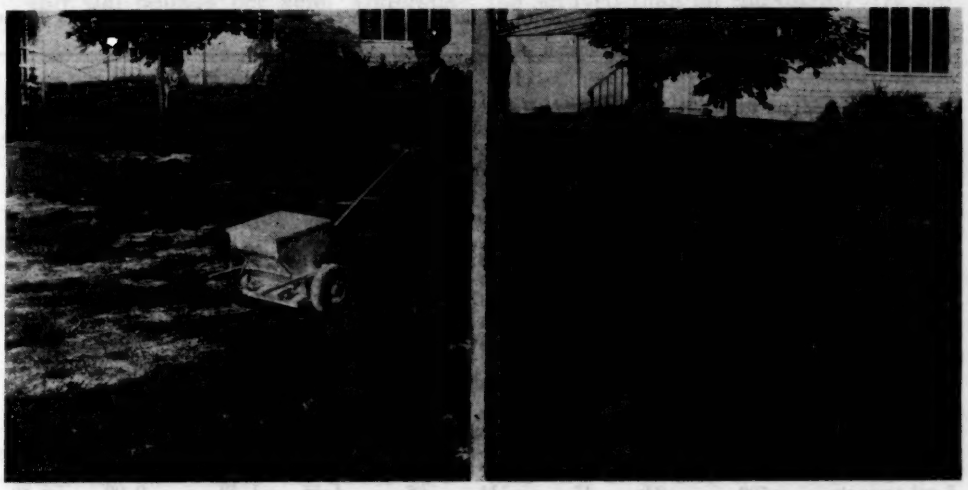

FIG. 1.—European chafer control—*left*, grub damage to lawn at time of application of arsenate of lead at 500 pounds per acre; *right*, same lawn 18 months after treatment.

located at depths of from 3 to 6 inches from the surface which is apparently below the most effective poison zone. Preliminary records taken in the fall of 1942 and the spring of 1943 failed to show any appreciable reductions in the grub population of the treated plots. Data from the same plots taken in 1943 and 1945 are given in table 1.

1943 EXPERIMENTS FOR CONTROL OF LARVAE.—During 1943 the following treatments were applied on twentieth-acre plots: (1) a mixture containing 1000 lbs. of dusting sulfur and 75 pounds of lead arsenate per acre; (2) micronized sulfur, 1000 pounds per acre; (3) lead arsenate, 500 pounds per acre; (4) calcium arsenate, 500 pounds per acre. All of these materials were applied with a hand fertilizer distributor after being mixed with a No. 1, washed masons sand at the rate of 1 part by weight of the insecticide to 4 or 5 parts by weight of sand. Treatments were made between June 18 and July 6, inclusive, during the period when adults were emerging and laying eggs in the soil. The micronized sulfur treatment caused severe injury to the 1943 re-seeded turf and the calcium arsenate application also caused noticeable burning of the grass. The sulfur treatments were applied with the object of determining their possible value as repellents in preventing oviposition. Records on infestation are given in table 1.

1944–45 EXPERIMENTS FOR CONTROL OF LARVAE.—Soil treatments during 1944 were limited to the application of DDT at rates of 15, 30 and 50 pounds per acre. DDT was used both in the form of an emulsion (*Gesapon No. 18*)[1] and as a suspension (*AK 20*),[1] all treatments being replicated twice. The necessary amount of DDT per plot was mixed with 2 gallons of water and applied with a sprinkling can uniformly over the plot which was 10 by 10 feet in area. Treatment was made

[1] Geigy Company, New York.

Table 1.—Effect of various turf treatments on larvae of the current and later generations of the European chafer.

TREATMENT	LBS. PER ACRE	NO. DIGGINGS		TOTAL GRUBS		GRUBS PER SQ. FT.		PER CENT REDUCTION	
		Apr. 1943	Apr. 1945	Apr. 1943	Apr. 1945	Apr. 1943	Apr. 1945	Apr. 1943	Apr. 1945
EXPERIMENT 1—applied July 1942 on 1942–43 brood of grubs									
Lead arsenate	250	5	43	23	204	4.60	4.51	23.33	19.17
	500	5	43	29	106	5.80	2.46	3.33	55.91
	1000	4	43	23	32	5.75	0.74	4.16	94.82
	1500	3	34	14	4	4.66	0.11	22.33	98.02
Check	None	8	36	48	201	6.00	5.58	—	—
		Apr. 1944	Apr. 1945	Apr. 1944	Apr. 1945	Apr. 1944	Apr. 1945	Apr. 1944	Apr. 1945
EXPERIMENT 2—applied June–July 1943 on 1943–44 brood of grubs									
Dusting sul.-lead	1000	21	43	42	98	2.00	2.27	37.05	64.19
Lead arsenate	500	25	43	114	66	4.56	1.53	0.00	75.86
Calcium arsenate	500	20	43	59	67	2.95	1.55	7.81	75.55
Check	None	20	43	64	273	3.20	6.34	—	—
		Nov. 1944	Apr. 1945	Nov. 1944	Apr. 1945	Nov. 1944	Apr. 1945	Nov. 1944	Apr. 1945
EXPERIMENT 3—applied Sept. 12, 1944 on 1944–45 brood of grubs									
DDT emulsion	15	10	20	53	73	5.30	3.65	27.59	27.86
DDT emulsion	30	10	20	28	31	2.80	1.55	61.74	69.36
DDT emulsion	50	10	20	30	35	3.00	1.75	59.01	65.41
DDT suspension	15	10	20	35	31	3.50	1.55	52.18	69.36
DDT suspension	30	10	20	26	17	2.60	0.85	64.61	83.20
DDT suspension	50	10	20	19	13	1.90	0.65	74.04	87.15
Check	None	25	50	183	253	7.32	5.06	—	—

on September 12 and on this date approximately 75 per cent of the larvae were in the third instar. Two weeks after the application a number of dead or dying larvae were observed on the surface of the grass. No injury has been observed to grass following any of the DDT treatments. Records on grub reduction during the fall of 1944 and spring of 1945 are shown in table 1.

More extensive turf treatments were begun during the fall of 1945 to determine the residual effect of DDT at rates of 25, 50 and 200 pounds per acre. Materials were used both in the form of a suspension (*AK 40*) and as a 20 per cent emulsion[1]. All materials were applied with a power sprayer at 250 to 300 pounds pressure. Injury to foliage of clover was evident within 2 hours after application where the emulsion was used at amounts to give 50 and 200 pounds of DDT per acre, but no apparent injury to either clover or turf has been observed to date on those plots which were treated with the DDT in suspension. Detailed records of the effect of these treatments upon larval populations will be taken at a later date.

1944–45 TESTS ON ADULTS.—In 1944 preliminary field tests were conducted on American elm and Scotch pine to determine the effect upon the adults of a DDT spray suspension (*AK 20*) applied at the rate of 8 ounces of DDT to 100 gallons of water. Trees were sprayed in the evening of June 22 with a power sprayer operated at 300 pounds pressure, both before beetles emerged from the soil and after they had come to rest in the trees, to determine the effect of DDT upon beetles actually hit with the spray, as well as upon those coming in contact with DDT upon the foliage and branches after the trees were sprayed. In both instances DDT caused large numbers of beetles to fall to the ground on the night the application was made. On succeeding nights relatively fewer beetles were recovered. A number of affected beetles were observed to oviposit before death occurred 2 to 4 days after exposure.

During the latter part of the adult emergence period in 1945 a 3 per cent DDT-pyrophyllite dust and a spray containing 5 pounds of DDT suspension (*AK 40*) in 100 gallons of water was applied on black walnut trees at 7:00 P.M. on July 19. Large strips of cheesecloth were placed on the ground under treated and untreated trees immediately after the application so as to recover any beetles which fell out of the trees. Detailed records are given in table 2. In most instances the beetles collected on cloths under treated trees were dead within 2 to 4 days following exposure; however even when exposed to these heavy dosages of DDT some females deposited from 1 to several eggs before they died. It will be observed in table 2, that the residual effect of DDT was more pronounced on the sprayed than on the dusted tree following the heavy rain which occurred on July 22nd.

DISCUSSION OF RESULTS.—All of the population counts given in table 1 are of third instar larvae. While there appeared to be a slight improvement in the appearance of grass during the fall of 1942 and the spring of 1943 on those plots which received treatment during the summer of 1942, limited digging records failed to show any consistent reductions in grub populations as compared with untreated plots. This possibly may be accounted for in part by the limited number of observations, variation in infestation from plot to plot, disproportionate reduction in grub population of treated and untreated plots by birds and lack of proper distribution and penetration of arsenical through the root zone. It is also true that, possibly because of hot, dry soils, a large percentage of the grubs were feeding most of the summer below the depth at which most of the poison is located. The influence of hot, dry soils was illustrated in records obtained from diggings which were made throughout the summer and in which it was observed that most larvae were located at depths of from 4 to 6 inches prior to the first heavy rains which occurred in September. Within 24 hours after the rain the majority of the larvae had moved upward from the 4- to 6-inch depth to the 0- to 2-inch soil level.

From observations made by the writer upon numerous lawns which have been treated with arsenate of lead during the past 5 years, both experimentally and for the suppression of the Japanese beetle within the *Amphimallon* infested area, it has become apparent that the general appearance of the lawn does not improve appreciably during the feeding period of the current generation of grubs present in

the soil at the time, or shortly after, the treatment is made. However, by the next year and with the next complete generation of grubs following treatment, there is a definite improvement in condition of the grass and a reduction in grub population. These observations definitely indicate that optimum soil temperatures for grub activity, alternate periods of freezing and thawing and adequate soil moisture, are of importance in the satisfactory distribution of lead arsenate in turf and subsequent grub control.

In the case of DDT, which appears to be much more rapid in its killing action on the grubs than is lead arsenate, extended periods of optimum temperature and soil moisture may be less important. For example, it may be observed in table 1 that DDT, even at the rate of 15 pounds per acre, effected a fairly high reduction in grub population within 2 months following application whereas lead arsenate applied in 1942 at the rates of 250, 500 and 1000 pounds per acre, showed little or no reduction in grub population on the current brood of grubs nine months following treatment. Similar results were obtained with both lead arsenate and calcium arsenate in 1943 when applied at the rate of 500 pounds per acre.

DDT when applied on trees as a suspension at the rate of 8 ounces in 100 gallons of water was effective in knocking down and killing the adults, either when they came to rest in the trees, following application, or when hit directly by the spray. The residual effect of DDT was noticeable for approximately one week following application; however, at the end of two weeks following treatment only 3.7 per cent of the adults were sufficiently affected to cause them to fall out of the trees. Beetles which fell from both treated and untreated trees on the fourth night after application were collected and held in cages for later observations. After one week it was observed that 13.8 per cent of the beetles from the sprayed trees and 24 per cent of those from the unsprayed trees were still alive. These records indicate that at such a low concentration DDT is not highly effective against the adults for any extended period. The records obtained from DDT treatments applied at higher concentrations in 1945 were somewhat more striking. As will be observed in table 2 a DDT spray applied at the rate of 5 pounds of DDT (12.5 pounds of *AK 40* in 100 gallons of water) was still quite effective against adults one week after application as compared with untreated trees, whereas the trees which received a 3 per cent DDT dust showed little effect upon the beetles following a heavy blowing rain which fell on the morning of July 22nd. In most instances adults which were knocked

Table 2.—Residual effect of DDT on European chafer adults migrating into dusted and sprayed trees on successive nights following treatments.[1]

Dates Counted	Position of Beetles[2]	No. Beetles Counted			Per Cent Beetles Counted		
		Dusted	Sprayed	Untreated	Dusted	Sprayed	Untreated
7/20	in tree	0	0	216	0.0	0.0	91.5
	on cloth	32	51	20	100.0	100.0	8.5
7/21	in tree	1	0	237	2.6	0.0	84.9
	on cloth	76	132	42	97.4	100.0	15.1
7/22[3]	in tree	6	1	144	18.8	2.8	92.9
	on cloth	26	35	11	81.2	97.2	7.1
7/23	in tree	8	3	105	66.6	33.3	96.3
	on cloth	4	6	4	33.3	66.6	3.7
7/24	in tree	23	1	67	85.2	2.5	98.5
	on cloth	4	40	1	14.8	97.5	1.5
7/25	in tree	30	5	63	93.7	21.8	92.7
	on cloth	2	18	5	6.3	78.2	7.3
7/26	in tree	12	0	44	92.4	0.0	80.0
	on cloth	1	8	11	7.6	100.0	20.0

[1] Materials were applied at 7:00 P.M. July 19, 1945 and records were taken at 4:00 A.M. on dates indicated.
[2] After first removing and counting the beetles which fell onto the cloth during the night those beetles remaining in the trees were knocked down and counted at 4:00 A.M.
Very heavy, blowing rain between 6:00 and 8:30 A.M.

down by DDT were dead within 72 hours but during this time some beetles deposited several eggs before death occurred.

SUMMARY.—The European chafer was first observed in North America in 1940 and has become established over an area of approximately 150 square miles in western New York. In a rather limited area of some 10 square miles, serious damage has been observed in turf of lawns, golf courses, parks and cemeteries, as well as to grass in pastures and to wheat fields. This species has a 1-year life cycle, for the most part, and causes injury very similar in appearance to that of the Japanese beetle and of native species of white grubs.

Lead arsenate has been applied at rates of from 250 to 1500 pounds per acre; calcium arsenate at 500 pounds per acre; dusting sulfur and micronized sulfur at 1000 pounds per acre; DDT emulsions and suspensions at 15, 30, 50 and 200 pounds per acre. Dosages of 250 pounds of lead arsenate per acre have proved inadequate for grub-proofing turf. Lead arsenate applied at the rate of 500 pounds per acre has afforded commercial protection of turf for periods of 2 to 4 years (55.9 to 75.9 per cent reduction in grub population) but when applied at the rate of 1000 to 1500 pounds per acre excellent protection has been afforded over a period of 4 years.

DDT when applied to the turf as a suspension at the rate of 30 and 50 pounds per acre appears promising for the control of larvae. In limited tests 30 pounds of DDT per acre proved as effective as 500 pounds of lead arsenate. Likewise, DDT effected a much higher percentage of grub reduction within 2 months than did 500 pounds of lead arsenate in the first year following application. Further and more extensive field tests with DDT as a larvicide are under way.

A DDT spray suspension applied on trees at the rate of 8 ounces in 100 gallons of water, knocked down and killed adults which came to rest in treated trees for several days following application but was less effective than the same material applied at the rate of 5 pounds in 100 gallons of water. Even at the higher concentration some gravid females deposited eggs before they died. The effect of such a treatment upon the reduction in grub population has not been determined.—1-28-46.

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RESULT OF LETTER BALLOT

The results of the letter ballot on the question of a gift of $2,000.00 to the A.A.A.A. for their building fund have now been tabulated and show 702 in favor of and 31 opposed to the gift. The results of the ballot are sufficiently clear cut. But the arguments in favor of balloting by letter on important matters, rather than by a vote of the members in attendance at the annual meetings, do not seem to be well supported by the size of the vote. Only about 40 per cent of the members took the trouble to vote. These are doubtless the members who attend the meetings whenever possible and the same ones who would have decided the motion had it been put in a regular business session of our Association.

Chemical Methods for Analysis of Dichloro-diphenyl-trichloroethane (DDT)

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The extraordinary insecticidal properties of DDT, as revealed by many entomological investigations, made it the outstanding new insecticide developed during World War II. However, in addition to its high toxicity to insects it is also poisonous to man and higher animals and may, if not properly employed, constitute a health hazard as shown by Lillie & Smith (1944), Smith & Stohlman (1944), Nelson (1944), Neal (1945), Smith and Stohlman (1945), and others. Due to the recent release of DDT for unlimited civilian use, a reliable chemical method for its analysis in spray residues and in commercial insecticides is of primary importance.

Commercially, DDT is now prepared by the condensation of chloral with chlorobenzene in the presence of concentrated sulfuric acid, involving the following reaction:

$$CCl_3CHO + 2C_6H_5Cl = (C_6H_4Cl)_2CHCCl_3 + H_2O.$$

The technical grade consists largely of two isomers:

(I) P,P′-DDT = 1-trichloro-2,2-bis(p. chlorophenyl)ethane

(II) O,P′-DDT = 1-trichloro-2,0-chlorophenyl-2-p.chlorophenyl ethane.

Small quantities of other isomers, by-products and impurities are also present. The P,P′-DDT isomer constitutes the major part of the technical grade, varying from 70 to 80 per cent, Crystol (1945), whereas the O,P′-isomer is a minor quantity of some 15 to 20 per cent.

DDT possesses a complex molecule consisting of aromatic and aliphatic structures, with chlorine in both groups. Several chemical methods of analysis, based on reactions with either the aromatic group (-diphenyl), the aliphatic group (-chloroethane), or on the decomposition of the entire molecule are now being tested by many investigators. In this paper the principles of the various methods are briefly described and the original publications, where details of procedure are set forth, indicated. A brief classification of the methods now under investigation is presented in Table 1.

Table 1.—Classification of chemical methods for determining DDT.

I. *Colorimetric Methods*
A. Pyridine-xanthydrol reaction
B. Friedel-Craft reaction
C. Nitrated DDT in Na-methylate reaction.
II. *Volumetric Methods*
A. Total organic chlorine
1. Combustion—by modified winter method
2. Reduction—by metallic sodium in benzene
3. Reduction—by metallic sodium in alochol
B. Labile chlorine
III. *Gravimetric Methods*
A. Crystallization of P,P′-DDT isomer

DESCRIPTION OF METHODS.—I. *A.* The principle of this method, as described by Stiff and Castillo (1945), depends on the formation of a red color when DDT is heated in an anhydrous pyridine solution containing xanthydrol (9-hydroxy xanthene) and solid potassium hydroxide. The intensity of the color is proportional to the amount of DDT present.

Preliminary tests with this method in our laboratory have shown it to be highly sensitive, detecting as little DDT as 1:4000,000, but the presence of sulfur in spray mixtures interfered with the color development. However, Irreverre and Sharpless (1945) report that similar color reactions were obtained with 18 analogs and derivatives of DDT.

B. Friedel-Craft reaction.—The principle of this method, as reported by Bailes & Payne (1945), depends on the formation of a colored compound when either pure 1-trichloro-2,2-bis(P-chlorophenyl) ethane or technical DDT dissolved in benzene is heated with anhydrous aluminum chloride. The intensity of the color, orange by transmitted light and greenish orange by reflected light, gives a quantitative measurement of the DDT. This may offer a quick method for analyzing DDT in spray residues, provided that other materials present in spray mixtures do not interfere with the color formation, which is a subject for further investigation.

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C. Nitrated DDT and Sodium Methylate.—The sample of DDT is first nitrated with a mixture of concentrated H_2SO_4 and fuming HNO_3 by the procedure of Chechter *et al.* (1945). The nitrated compound is then taken up with benzene and treated with Sodium Methylate to develop the color. With technical DDT a mixture of two colored compounds is produced, blue for the P,P′-isomer and reddish-purple for the O,P′-isomer. The colors are measured with the help of two filters, or wave length settings, or a filter photometer or spectro photometer. The value for each of the two isomers is calculated and their sum is equal to the total amount of DDT present in the sample. The details of this method are fully described in a mimeographed paper by the Food and Drug Administration (1945) for determining DDT in spray residue of apples.

II. *A. Total chlorine determination.*—The molecule of pure DDT contains five organically bound chlorine atoms, constituting 50 per cent of its weight. Determination of total chlorine offers, therefore, a method for analyzing DDT, provided of course that other chlorine compounds are not present or can be eliminated from the reactions involved. Accurate methods for determining chlorine in organic compounds have been developed long before DDT appeared in the scene. However, modifications became necessary for DDT determination in order to eliminate interfering substances present in spray mixture. In general, the principle of the method consists of decomposing the DDT and converting the organic chlorine by either reduction or combustion to water soluble inorganic chlorides such as NaCl, which can be readily determined by the Standard Volhard Method. The chloride ion in solution is titrated with an excess of a standard silver nitrate soluiton and back titrated with standard soluitons of either KSCN or NH_4SCN in the presence of either ferric nitrate or ferric ammonium sulfate indicators. Since the chlorine content of DDT is 50 per cent, the amount of chlorine obtained multiplied by a factor of 2 will be the equivalent of DDT present in the sample. Several modifications of this method for converting the organic chlorine in DDT to inorganic chlorides have been worked out and are now under test.

1. *Combustion by Modified Winter Method.*—The procedure is fully described by Hall (1944) and by Fahey (1945). Briefly, the sample of DDT, dissolved in either acetone or benzene, is volatilized in an electrically heated U-shaped glass tube and burned in a flame of illuminating gas in an apparatus especially constructed for this purpose. The combustion products containing the chlorine are aspirated and absorbed in an alkaline solution of sodium arsenite. This solution is then titrated for chlorine by the Volhard method, using standard solutions of silver nitrate and ammonium thiocyanate and the per cent DDT calculated.

2. *Reduction by Metallic Sodium in Benzene.*—This procedure, modified from Stepanow's method (1906), is described by the Food and Drug Administration (1945). The sample of DDT, dissolved in benzene, is refluxed with metallic sodium in the presence of isopropyl alcohol as catalyst until all is in solution. The chloride is then titrated by the Volhard Method.

3. *Reduction by Metallic Sodium in Absolute Alcohol.*—This procedure, also a modification from Stepanow's Method is described by Smith & Stohlman (1944), used in determining DDT in animal tissue and fluid. In this case the DDT is first extracted from the sample by Soxhlet with either acetone or ether and the solvent volatilized. The dry residue is freed from inorganic chlorides and dissolved in absolute alcohol. The solution is then treated with metallic sodium under reflux condenser and the chloride determined by the Volhard Method.

B.—Labile Chlorine Determination.—When DDT is treated with dilute alcoholic potassium hydroxide a process of dehydrohalogenation takes place by which one chlorine atom in the aliphatic group of the molecule splits off and forms HCl which is readily converted to KCl leaving the unsaturated compound dichloro diphenyl dichloroethylene, according to the following reaction:

$$(C_6H_4Cl)_2CHCCl_3 + KOH = (C_6H_4Cl)_2CCCl_2 + KCl + H_2O.$$

This observation was made by Zeidler (1874), who was the first one to describe the compound now known as DDT. This reaction forms the basic principle of a quantitative method, developed by Neal (1944) and Gunther (1945), for analyzing

DDT. The details of procedure are described by Food and Drug Administration (1945).

Briefly, a solution of DDT in benzene is refluxed for 30 minutes with a solution of 2N. alcoholic potash. The labile Cl atom in each of the two DDT isomers is quantitatively converted to KCl and analyzed by the Volhard Method, using standard solutions of $AgNO_3$ and NH_4SCN. Since only one of the 5 Cl atoms is released the amount of chlorine found, multiplied by a factor of 10 gives the equivalent amount of DDT present in the sample.

III. *A.—Determination of P,P'-DDT isomer by crystallization.*—This method, as described by Cristol *et al.* (1945), consists of refluxing on a hot plate a known quantity of DDT mixture in an aqueous solution of 75 per cent ethyl alcohol, previously saturated with the pure P,P'-isomer (1-trichloro-2,2-bis(P.Chlorophenyl) ethane until all of the sample is in solution. Upon cooling the P,P'-isomer crystalizes out, whereas the O,P'-isomer and the other impurities remain in solution. The crystals are then filtered in a gooch crucible by suction, dried, weighed, and the per cent P,P'-DDT calculated. Although this method is primarily applicable to concentrated mixtures containing at least 40 per cent DDT, certain modifications in the basic procedure to allow for analysis of products containing smaller percentages of DDT are also indicated by the authors.

Results from preliminary tests with this method in our laboratory on samples of technical and purified grades of DDT are given in table 2. Since the P,P'-isomer is the largest component in technical DDT and is also considered the most toxic to insects, Haller *et al.* (1945), this method may offer a standard procedure for evaluating commercial DDT.

Table 2.—Analysis of P,P'-DDT-isomer.

Test No.	DDT Grade Tested	Average Per Cent P,P'-DDT
1	Technical—commercial	76.00
2	Technical—commercial	76.66
3	Technical—commercial	69.53
4	Purified—commercial	97.72
5	Purified—laboratory	98.06

DISCUSSION.—While the methods here reviewed have been used with considerable accuracy for determining DDT in pure and technical grades, none of them is specific for DDT. Chloro-organic compounds related to DDT are subject to the same reactions. Such chemicals may be encountered in spray mixtures as by-products in the manufacture of DDT; as ingredients present in insecticide and fungicide sprays; as impurities taken up with spray residues on fruit, and from other sources. Until a chemical method is developed with distinct specificity for dichloro-diphenyl-trichloroethane only, the methods now under investigation should be considered as temporary and used with caution. Likewise, discretion should be employed in evaluating results from DDT analysis on spray residues and commercial insecticide mixtures.

SUMMARY.—The principal reactions of eight chemical methods, now under investigation, for analyzing DDT in spray residues and insecticide mixtures are briefly reviewed.—1-9-46.

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The Mode of Toxic Action of Dinitro Compounds on the Honeybee[1]

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For a long time fruit growers have had to tolerate the low quality fruit of some biennial bearing apple varieties. To avoid this it has been the practice to remove some of the immature fruit by hand on heavily laden trees after the June drop. While this method was used for the want of a better one, it did not produce the desired results, for the trees had used energy at the expense of the foliage and the remaining fruit in developing the discarded apples.

The use of dinitro sprays as blossom thinners is a comparatively new practice and is still in the experimental stages. The rate of application depends on the type of tree and its vigor.

The dinitro most commonly used for this purpose is *Elgetol*,[2] a product whose active ingredient is the sodium salt of 3,5-dinitro-o-cresol. Flory & Moore (1944) got best results on York Imperial apples by using a 0.2 per cent *Elgetol* solution. They claimed that this concentration gave greatest economy, brought about a noticeable improvement in color and yielded the highest per cent of number one apples. Hoffman (1944) prevented the setting of fruit on Early McIntosh and Golden Delicious with a 0.1 per cent and 0.2 per cent solution of *Elgetol*. Howlett (1943) used 3.2, 2.4, 1.6 ozs. of dinitro-o-cresol and dinitro-o-cyclohexylphenol in oil emulsion on Cortland, Baldwin, Grimes Golden, Melba, Northern Spy, Oldenburg, and Wealthy; and he states that the 3.2 oz. concentration was too strong. Hoffman (1942) reports no serious injury by using 0.3 or 0.4 per cent *Elgetol* on vigorous Wealthies.

Much work has been done on the physiological effects of dinitro derivatives on a variety of animals and some plants but there is a dearth of information pertaining to their effects on insects.

While working on wax moth larvae, *Galleria mellonella* L., Croland (1937) found that sublethal doses of 2,4-dinitro-o-phenol ranging from 0.02 mg. to 0.06 mg. per gm. would increase the oxygen consumption with the maximum increase occurring at 0.036 mg. per mg. where the oxygen intake was doubled. Bodine & Boell (1936) using grasshopper embryos checked the effects of 2,4-dinitrophenol and 3,5-dinitro-o-cresol on respiration where the metabolism is predominately at the fat level. Maximum stimulation was found at 0.00025 molar concentrations of dinitrophenol. The oxygen uptake was about three times greater than normal. The dinitro-o-cresol reached maximum stimulation at 0.0001 molar concentrations with an increase in oxygen uptake of 2.5 times. These data show the dinitro-o-cresol to be about twice as active physiologically. This increased rate of respiration

[1] From the Laboratory of Insect Physiology, Cornell University, Ithaca, N. Y.
[2] Standard Agricultural Chemical Co.

was maintained for several hours for both substances. Stellwaag & Staudenmayer (1940) claimed that dinitro-o-cresol is capable of penetrating the lipoid containing exocuticular and the chitinous layers of the insect exoskeleton and exerts its toxic effect on living cells by the coagulation of protein.

Table 1.—Bee visits per tree for 2½ mins. out of every 10.

VARIETY	TREATMENT	TIME	BEE VISITS
McIntosh	Unsprayed	4¾ hours	109
	Sprayed	4¾ hours	233
Wealthy	Unsprayed	4¾ hours	255
	Sprayed	4¾ hours	282
Baldwin	Unsprayed	5 hours	15
	Sprayed	5 hours	35

The toxicological aspects of dinitro compounds have been studied for a number of insects, but not the honeybee. This has a direct legal bearing on spray recommendations should it be toxic, for Gould (1938) quotes N. Y. penal law (1757) as saying "Any person who will spray or apply in any way poisons or any poisonous substance to fruit trees while the same are in bloom is guilty of a misdemeanor punishable by a fine of not less than ten dollars ($10) or more than fifty dollars ($50)."

The median lethal dose is recorded for a few insects. Croland (1937) found that 2,4-dinitrophenol was fatal to the wax moth at 0.06 mg. per gm. Kagy (1936) using 2,4-dinitro-o-cyclohexylphenol computed the following medial lethal doses:

Heliothis armigera Hbn. (Corn Earworm)—.087 mg. per gm.
Criphis unipuncta Haw. (Armyworm)—.015 mg. per gm.
Pieris rapae (L) (Imported Cabbage Worm)—.073 mg. per gm.
Melanopus femur-rubrum DeG. (Red-legged Grasshopper)—.065 mg. per gm.

In all cases DN was found to be more toxic than acid lead arsenate and much more rapid in toxic action.

MATERIALS AND METHODS.—Bee visits to sprayed and unsprayed blossoms of McIntosh and Wealthy trees were recorded. About 30 to 40 minutes after spraying when the leaves and petals were dry, an increase in bee visits became apparent. In both cases the sprayed trees were visited more often over a period of hours immediately after spraying. Baldwins on the other hand showed no increase in bee visits but a marked decrease of about 78 per cent.

Two hives were put in an orchard where trees were to be sprayed. The complete brood in both was mapped on cellophane prior to and 4 days after spraying and careful comparison of these showed that no damage had been done on this occasion. Moreover, dinitro could not be demonstrated in the nectar taken from bees working sprayed blossoms.

Chemical analysis of leaves and petals was carried out to determine whether any hydrolysis or oxidation of the dinitro occurred and by doing so reducing the toxicity of the residue. The method of analysis was supplied through the courtesy of *Dow Chemical*. For the computing of total dinitro, the dry sample was acidified and extracted in petroleum ether. The dinitro was removed from the petroleum ether as the sodium salt in 0.1 per cent sodium bicarbonate solution, which generated a yellow color. A *Lumentron* colorometer (*Model 402 B*) fitted with a light filter having its transmission peak at 440 mu. was used for measuring the intensity of this yellow color. For a comparison, a water extract of the sample was made and the dinitro recovered from this as previously described. No significant difference was noted for the residues on petals while the leaves showed a lower dinitro content for the petroleum ether extract.

Chemical analysis of pollen taken from bees forced to work sprayed blossoms showed only an insignificant trace of dinitro (0.002 p.p.m.). Table 2

The susceptibility of the honeybee to

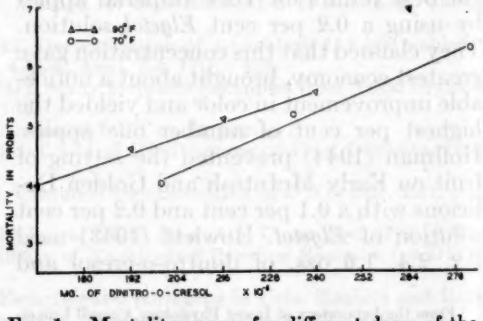

FIG. 1.—Mortality curves for different doses of the sodium salt of 3,5-dinitro-o-cresol at 70° and 90°F.

Table 2.—Chemical analysis of residues on leaves and petals.

SAMPLE	WEIGHT IN GM.	SOLVENT	TOT. VOL. OF EXTRACT IN ML.	DINITRO P.P.M. In Extract 1	2	3	Av.	On sample
Petals 36 hours after spraying	0.7384	Pet. Eth.	50	68.8	68.8	66.3	68.0	4600
	0.100	Water[1]	25	13.74	18.70		16.2	4050
Petals from dead plants	0.300	Pet. Eth.	25	24.5	24.8	21.5	23.6	1970
	0.100	Water	25	7.75			7.8	950
Petals 3 days after spraying	0.400	Pet. Eth.	50	5.75	5.72	5.60	5.7	717
	0.200	Water	25	4.16	4.55		4.4	550
Leaves 3 days after spraying	0.400	Pet. Eth.	50	1.53	1.53		1.5	188
	0.300	Water	25	2.75			2.7	226
Leaves 12 hours after spraying	0.400	Pet. Eth.	50	.60	.65		.6	75
	0.300	Water (Rain)	25	1.75			1.7	142

[1] Rainwater was used in all tests to approximate natural conditions.

this poison has a direct legal bearing on concentrations used in the field, hence the establishment of the median lethal dose (Fig. 1) became necessary. To do this, bees were fed doses of .004 ml. of a dinitro: sugar syrup mixture of known concentration. The mortality at the end of 24 hours was recorded. From this the MLD for the sodium salt of dinitro-o-cresol was computed to be 0.00239 mg. per bee at 70° F. and 0.00213 mg. per bee at 90° F. Also it was calculated, that a bee need only consume 0.0028 ml. to get a lethal dose of dinitro spray containing one ounce of active ingredient per 100 gallons.

The dinitro causes a common phenomenon on most living organisms, that is, an increased oxygen consumption brought about by an upset of oxidative metabolism. The bee is no exception to this and tests were run to determine to what extent sublethal doses affected them. A Warburg respirometer was constructed to accommodate four bees which were used in each determination. The temperatures used were 80°, 90°, 96° and 105° F. Of these 105° F. gave the lowest consumption of oxygen, moreover the oxygen consumption—time curve was the nearest approach to a straight line. As temperature decreased the oxygen consumption increased (Fig. 2).

Concentrations as low as one-sixth of the MLD[1] increased the oxygen consumption 52 per cent, and one-sixtieth of MLD brought about a 28 per cent increase. (Figs. 3 and 4).

DISCUSSION.—To date no damage to brood has been recorded, and no dinitro was recovered in nectar or on pollen taken from bees which were working on sprayed

[1] The median lethal dose is reported as that concentration at which 50% mortality occurred instead of mg. per gm. body weight, because the adult bee is capable of carrying its own weight in food and the average weight varies from 0.07 gm. to 0.12 gm. depending on the food content of the honey stomach.

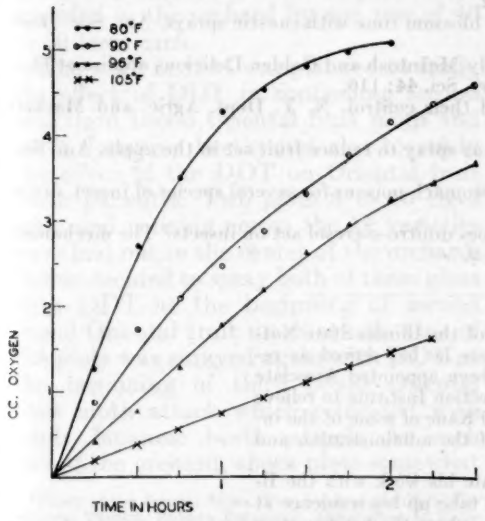

FIG. 2.—The effect of different temperatures on the oxygen consumption of bees fed .004 ml. sugar syrup.

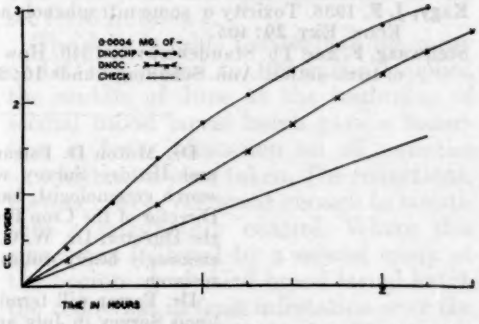

FIG. 3.—Oxgen consumption of bees when fed 0.0004 mg. of the sodium salts of 3,5-dinitro-o-cresol and 2,4-dinitro-o-cyclohexylphenol.

blossoms. This does not free the dinitro compounds of their great potential threat to brood.

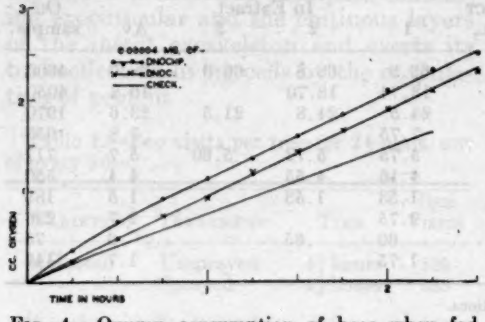

FIG. 4.—Oxygen consumption of bees when fed 0.00004 mg. of the sodium salts of 3,5-dinitro-o-cresol and 2,4-dinitro-o-cyclohexylphenol.

Under normal circumstances bees will not visit wet blossoms, but will wait till the spray has dried before going to work. In very dry years bees have been known to collect spray materials while in search of water, and this possibility is not to be overlooked for the dinitro sprays. The lower the temperature, the greater will be the losses for the toxicity and oxygen consumption are increased as the temperature decreases.

The analytical work showed that the residues were very soluble in water hence not present as the free phenol, which is insoluble. Therefore, we can expect damage to field bees consuming the residues should they get back into solution upon subsequent wetting.

CONCLUSIONS.—This work has brought to light several facts whlch can be summarized as follows:

(1) Dinitro salts (Sodium salt of 3,5-dinitro-o-cresol and sodium salt of 2,4-dinitro-o-cyclohexylphenol) are very highly toxic to the honeybee.

(2) The dinitro compounds do not decompose but remain potentially toxic for some time after application.

(3) There is a varietal difference in the attractiveness of sprayed blossoms to bees.

(4) The median lethal dose for the sodium salt of 3,5-dinitro-o-cresol is .0021 mg. per bee.

(5) Doses as small as 0.00004 mg. of Sodium salt of 3,5-dinitro-o-cresol has a measurable effect on the adult bee.

(6) The toxic effect of these dinitro compounds is faster at lower temperatures.—1-16-46.

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Dr. Milton D. Farrar, of the Illinois State Natural History Survey where he has served as research entomologist, has been appointed Associate Director of the Crop Protection Institute to relieve the Director, Dr. W. C. O'Kane of some of the increasingly heavy duties of the administration and research.

Dr. Farrar will terminate his work with the Illinois Survey in July and take up his residence at Durham, New Hampshire, where the headquarters of the Institute are located.

DDT on Peaches: Three Years Field Experiments[1]

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During the seasons of 1943, 1944 and 1945 the writer, in cooperation with Dr. W. E. Fleming of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, carried on orchard spraying experiments on peaches to study the value of DDT as a control for the Oriental fruit moth and the adult Japanese beetle. The experiments were carried on in the same orchard each year on twelve varieties of peaches commonly grown in New Jersey and included early, midseason and late ripening varieties.

The data obtained from the experiments in 1943 as related to Oriental fruit moth control were published in 1944.[2] The results from the preliminary experiments in 1943 showed a high degree of control of Oriental fruit moth on varieties harvested 2 to 3 weeks after one spray application of DDT.

DDT IN 1944.—The cooperative work with DDT on peaches was continued in 1944 in the same orchard used for the 1943 experiments. The orchard consisted of one row each of the varieties Raritan Rose, Cumberland, Triogem, Golden Globe, Red Rose, Sun High, Golden East, Summer Crest, Elberta, J. H. Hale, and the unnamed New Jersey Agricultural Experiment Station varieties no. 109 and no. 118. Each variety was represented in the orchard by one row of 40 to 50 trees each.

The work in 1944 was planned to study the effect of DDT in controlling second and third brood Oriental fruit moth and adult Japanese beetle and also to study the effect of the DDT on Oriental fruit moth parasites. Two plots 8 to 10 trees wide and running across the 12 varieties were laid out in the center of the orchard. It was decided to spray both of these plots with DDT at the beginning of second brood Oriental fruit moth attack. One of the plots was sprayed again with DDT at the beginning of third brood Oriental fruit moth attack which coincided with adult Japanese beetle attack. At each end of the orchard, check plots somewhat larger than the sprayed plots were left unsprayed. The DDT was used at the rate of 1 pound actual DDT to 100 gallons water. The DDT used consisted of technical DDT micronized with an equal amount of pyrophyllite. It was prepared by Dr. Fleming. A pint of a water solution of fish glue (1 pound fish glue in 1 gallon of water) was used to wet the DDT-pyrophyllite which was then added to the spray tank. One quart of 83 per cent summer oil emulsion was added to each 100 gallons of the diluted spray to serve as a sticker.

The first application of the DDT spray was made on both plots June 16 and 17. One of the plots was sprayed a second time on July 14. The two DDT-sprayed plots and the two check plots at each end of the orchard received the regular shuck-split and 10-days-after-shuck-split sprays of lead arsenate-sulfur-lime. All of the plots received an additional spray of sulfur and lime 2 weeks after the 10-day spray.

Oriental fruit moth-injured fruit was determined in the two DDT sprayed plots and the two check plots by examining all the fruit on one tree in each plot of each variety. This gave the percentage of so-called visible injury. Part of the apparently sound fruit was then sliced to determine the invisible injury.

Seven of the 12 varieties were examined for Oriental fruit moth injury in each plot. The seven included a succession of varieties ripening 3 to 6 weeks after the last DDT spray was applied July 14. The data from the fruit examinations are set forth in table 1.

The data in table 1 show that one spray of DDT 1 pound to 100 gallons applied the middle of June at the beginning of second brood larval hatch gave a reduction in fruit infestation on all varieties on which data were taken. The reductions, however, were not great enough to constitute a satisfactory control. Where this spray was followed by a second spray at the beginning of third brood larval hatch the reduction in fruit infestation over the unsprayed check ranged up to 90 per cent or better. Since the fruit from unsprayed

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

[2] JOUR. ECON. ENT., 37(1): 120.

check trees ran as high as 20 to 30 per cent injured fruit such reductions would constitute a satisfactory or commercial control of the fruit moth.

DDT IN 1945.—The experimental work was continued in 1945 in cooperation with Dr. Fleming of the Japanese Beetle Laboratory. The same orchard and varieties were used in laying out the plots as were used in 1943 and 1944. For the third season's tests with DDT in this orchard it was decided to limit the spraying to the third brood of Oriental fruit moth and adult Japanese beetle. The work of the previous season indicated that second brood spraying alone would not give satisfactory control of the fruit moth and there was the added danger of upsetting the work of parasites which normally reduce the moth population to a considerable degree by destroying second brood twig feeding larvae.

Table 1.—Oriental fruit moth control on peaches sprayed with DDT once (June 16) and twice (June 16 and July 14) using 1 pound of DDT to 100 gallons water.

Plot No.	Treatment	No. Peaches Examined	% Visible Injury	No. Peaches Sliced	% Invisible Injury	% Total Injury
	Raritan Rose, Harvested 8/7 to 8/10/44					
1	Check	600	1.0	150	1.3	2.3
2	DDT Twice	800	0.0	175	0.0	0.0
3	DDT Once	800	0.3	200	2.5	2.8
4	Check	800	1.0	200	6.0	6.9
	Cumberland, Harvested 8/7 to 8/10/44					
1	Check	500	2.0	150	7.3	69.1
2	DDT Twice	700	0.1	175	0.6	0.7
3	DDT Once	800	0.7	175	4.6	5.3
4	Check	700	3.4	175	15.4	18.3
	Triogem, Harvested 8/14 to 8/16/44					
1	Check	800	8.1	175	14.3	21.2
2	DDT Twice	800	1.1	175	4.0	5.0
3	DDT Once	800	5.6	175	7.0	12.2
4	Check	800	6.8	175	12.5	18.4
	Sun High, Harvested 8/18 to 8/21/44					
1	Check	700	9.4	175	17.3	25.1
2	DDT Twice	700	.7	175	2.0	2.7
3	DDT Once	700	4.5	175	10.7	14.6
4	Check	700	12.9	175	18.6	29.0
	Golden East, Harvested 8/21 to 8/25/44					
1	Check	600	17.7	—	—	—
2	DDT Twice	600	.7	—	—	—
3	DDT Once	600	8.2	—	—	—
4	Check	600	9.5	—	—	—
	Summer Crest, Harvested 8/25 to 8/30/44					
1	Check	600	16.0	—	—	—
2	DDT Twice	650	0.6	—	—	—
3	DDT Once	550	10.3	—	—	—
4	Check	550	19.0	—	—	—
	Elberta, Harvested 9/1 to 9/6/44					
1	Check	800	14.9	150	11.3	24.5
2	DDT Twice	700	0.0	150	.6	0.6
3	DDT Once	—	—	—	—	—
4	Check	800	16.5	150	18.0	31.5

It was further decided to test several brands and formulations of DDT to determine if there was any difference in control with the different formulations. Two commercial brands were selected, one supplied by the Geigy Company and known as *AK 40* contained 40 per cent DDT. The other, known as *Deenate* and containing 25 per cent DDT, was supplied by the E. I. du Pont de Nemours Company. In addition, a technical grade of DDT and a purified grade of DDT (melting point 107° C.) were obtained from Merck and Company. Part of the purified and technical grade DDT was micronized with equal parts of pyrophyllite and part of each grade was mixed with equal parts of clay in a hammermill.

The micronized and hammermilled DDT was prepared for the spray tank by adding 1 pint of fish glue (1 pound fish glue to 1 gallon water) to each two pounds of the 50 per cent DDT mixture. This was then added to the spray tank with 100 gallons water. The fish glue was not added to the commercial preparations because they already contained conditioning agents. All of the DDT mixtures were used at the rate of 1 pound actual DDT to 100 gallons water. One quart of an 83 per cent summer oil emulsion was added to the diluted spray to serve as a sticker.

The entire orchard, made up of 12 varieties of peaches, was used to lay out 10 plots, each plot 4 to 5 trees wide and running across the 12 varieties. The two end plots were left unsprayed to serve as checks and in addition two unsprayed check plots were interspersed in the DDT plots in such a way that each DDT treatment was next to an unsprayed check.

All of the DDT plots were sprayed on July 12 at which time third brood fruit moth eggs were beginning to hatch and adult Japanese beetle were beginning to come into the orchard. All of the plots were sprayed from the ground using a single nozzle gun operated from a Bean sprayer carrying 400 pounds pressure.

In addition to the one DDT spray on July 12 the entire orchard received the usual shuck split and 10-day sprays of lead arsenate-lime-sulfur during May plus three additional sprays of flotation sulfur during June, July and August.

Five of the 12 varieties represented in the plots were selected to make harvest fruit examinations. These were Cumberland, Triogem, Sun High, Summer Crest and Elberta, ripening respectively 18, 23, 28, 36 and 43 days after the DDT spray was applied. One tree of each variety in

each plot was selected and all fruit, including drops, were examined for visible injury. Part of the apparently sound fruit was then sliced to determine the so-called invisible injury. The data thus obtained are set forth in table 2.

Table 2.—Oriental fruit moth control with different DDT formulations used at rate of 1 pound DDT to 100 gallons and applied once at beginning of third brood egg hatch.

Plot No.	Treatment	Percentage O.F.M. Injured Fruit on: Cumberland	Triogem	Sun High	Summer Crest	Elberta
1	Check	5.3	18.5	15.9	17.0	24.5
2	*AK 40*	1.5	3.9	2.0	12.9	1.8
3	*Deenate*	1.3	1.3	2.4	3.3	2.6
4	Check	5.5	3.3	13.0	8.3	26.1
5	Technical DDT Micronized	2.3	7.3	2.5	4.6	24.4
6	Technical Hammermilled	2.6	10.1	0.5	2.4	19.3
7	Check	2.6	11.5	8.0	8.3	21.5
8	Purified DDT Micronized	3.4	5.3	6.0	12.3	9.7
9	Purified DDT Hammermilled	3.2	6.5	1.7	1.1	4.7
10	Check	8.2	15.0	12.8	28.4	27.8

An examination of the data in table 2 will show that the percentage injured fruit was generally lower in the DDT sprayed plots than in the unsprayed check plots adjoining. Even on Elberta which ripened 6 weeks after the spray was applied marked reductions in fruit injury were obtained with four of the six DDT formulations under test. Of the six DDT preparations, the du Pont product was consistently low on all 5 varieties. The *AK 40* and the purified DDT hammermilled were next with the remaining formulations low on some varieties and high on others.

EFFECT OF DDT ON OTHER INSECTS.—A great variety of insects present in the orchard at the time the DDT sprays were applied were killed. These included species from the orders Coleoptera, Diptera, Hymenoptera, Lepidoptera and Homoptera. This destruction of the orchard population of insects was observed all three years the experiments were run.

While the DDT sprays killed many species of insects it appeared to have the opposite effect on orchard mites, particularly the European red mite. A heavy build up of mites followed the use of DDT during the three year period. Whether this build up of mites was due to the destruction of the mite predators and parasites or to a change in the physiology of the mites or their host or both, is not known. The heavy build up of mites was noted each year on the peaches and on young apples interplanted with the peaches. In 1943 and 1944 mite injury was serious on both peaches and apples in this orchard following the use of DDT. Both years it was quite dry in July and August and heavy leaf drop occurred on the DDT plots. The season of 1945 was just the opposite being quite wet in July and August following the DDT sprays. While mite build up was noted on the DDT plots in 1945 the mites caused no serious leaf drop due, in part at least, to the heavy and frequent rains which tended to hold down the mites.

EFFECT OF DDT ON PLANTS.—Throughout the three years' tests a careful watch was kept to determine if any fruit or foliage injury appeared on the peaches and apples in the orchard. Also the weeds in and around the trees were observed. No direct injury from the DDT sprays to either apples or peaches was observed. Of some half dozen species of plants (clover, grass, weeds, etc.) observed in the orchard where drift from the DDT sprays fell on them, only crab grass was noticeably affected. After spraying the crab grass turned a reddish brown color but the grass was not killed. After two or three weeks the reddish brown color disappeared and the normal green color returned.

SUMMARY.—Three years orchard spraying experiments with DDT used at the rate of 1 pound DDT to 100 gallons water on peaches gave a high degree of control of Oriental fruit moth larvae attacking the fruit. One spray application timed to control the late broods of larvae gave effective control on varieties harvested 3 to 6 weeks after the spray was applied. European red mite built up in large numbers following the DDT sprays and caused heavy defoliation in two out of the three years.—1-21-46.

DDT and Other New Insecticides for Control of Cauliflower Worms on Long Island[1]

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The recent introduction and experimental use of new insecticides such as DDT (Annand *et al.* 1944) (Bruce & Tauber 1945) (Apple 1945) (Smith *et al.* 1945) and sabadilla (Brunn & Allen 1945) to combat insects injurious to cruciferous crops have prompted their further trial under Long Island conditions for control of various pests[2] attacking cauliflower. It was particularly desirable to note their effectiveness as compared to treatments involving the use of pyrethrum and rotenone-containing dusts.

Seedbed Tests Against Aphids and Thrips.—Two types of DDT-talc dusts and a mixture containing one of the analogues of DDT, dichloro-diphenyl-dichloroethane, were placed on trial. One type of DDT dust was prepared by the admixture of a finely ground concentrated powder containing technical DDT and pyrophyllite with talc, the second in a similar process involving the use of an impregnated inert powder possessing a concentrated strength of technical DDT in solution. Two types of sprays were included in the experiment, one a suspension of a finely ground concentrated mixture of technical DDT and a wettable powder, the other an emulsion of a solution of DDT. These sprays and dusts were formulated at various strengths in terms of active ingredients, and were applied in comparison with mixtures containing cube powder. Further details concerning their composition are given in table 1.

The experiment was carried out on five rows in the seedbed, on each of which rows the various plots representing the different treatments were arranged in a systematic series. The position of the series in each row was varied to permit as equable a distribution as possible in the experimental area.

The period of experimentation extended from June 26, when seedlings emerged above ground, to August 1, when plants were pulled and graded. Aphids and thrips were prevalent on seedlings as early as June 30, and had caused considerable injury to untreated plants by mid July, as is not unusual. An examination of plants in untreated plots on July 12 revealed an average population of 97 aphids and 8 thrips per seedling.

The period of treatment commenced on July 3 when most seedlings had developed their first true leaves, and ended following the last application on July 18. During this period three applications were made with weekly intervals between each. The average rate per application per 100 feet of row was 2, 5 and 5.5 ounces for dusts and approximately a gallon for sprays. In both instances materials were applied by hand machines. The effectiveness of different treatments was determined by the extent of seedling growth in the various plots as indicated by size and weight. Seedlings, on being counted, were grouped into three classes as denoted by the captions large, medium, and culls. The latter group included all types of seedlings remaining after the selection of plants belonging to the two former groups. Large seedlings from the various plots averaged 1.03 to 2.15 hundredths of a pound, medium 0.46 to 0.56 hundredths, and culls 0.14 to 0.2 hundredths. The data are summarised in table 1.

It will be seen from these data that dusts containing technical DDT were fully as effective as a cube mixture of 0.5 per cent rotenone content. The results obtained by the use of an impregnated dust, although not superior to that achieved by applications of a finely ground DDT-talc mixture of 2 per cent DDT strength, seemed particularly promising in view of the reduced strength of DDT required for effectiveness. A dust containing 2 per cent DDD (dichloro-diphenyl-dichloroethane) was slightly less effective for purposes of controlling a mixed infestation of aphids and thrips. Sprays containing a suspension of finely ground technical DDT in a wettable powder diluted in the spray to 0.05 per cent DDT strength, and those containing an emulsion of a solution of DDT diluted to half, or less than half, the foregoing strength, were about as effective as a

[1] Journal Paper No. 650, New York State Agricultural Experiment Station, Geneva, N. Y., November 28, 1945.

[2] *Myzus persicae* (Sulzer), *Thrips tabaci* Lindeman, *Pieris rapae* (L.), *Autographa brassicae* (Riley), *Plutella maculipennis* Curtis.

Table 1.—Effectiveness of DDT dusts and sprays for control of *Myzus persicae* and *Thrips tabaci* in the cauliflower seedbed as indicated by plant growth.

TREATMENTS	PER CENT ACTIVE INGREDIENTS	PERCENTAGE OF PLANTS			PERCENTAGE BY WEIGHT		
		large	medium	culls	large	medium	culls
Dusts							
DDT–talc[1]	2	48.5	19.6	31.9	85.8	9.1	5.1
DDT–talc	1	39.5	22.0	38.5	78.8	13.9	7.3
Impregnated inert,[2] less than 1% DDT		43.8	23.4	32.8	81.0	13.3	5.7
DDD–talc[3]	2	26.9	26.7	46.4	62.1	25.2	12.7
Cube powder 5% RC,[6] *Celite*, talc, 10-10-80 lbs.	0.5	37.1	27.2	35.7	73.1	19.2	7.7
Sprays (amounts per 100 gallons)							
Wettable powder 20% DDT,[4] 2 lb.	0.05	43.2	23.8	33.0	78.3	14.4	7.3
Wettable powder 20% DDT, 1 lb.	0.025	33.9	24.2	41.9	70.3	18.3	11.4
Wettable powder 20%, DDT, 8 oz.	0.0125	28.8	29.2	42.0	60.5	28.0	11.5
Oil emulsion 25% DDT,[5] 0.8 pint	0.025	52.8	21.0	26.2	86.8	9.5	3.7
Oil emulsion 25% DDT, 0.4 pint	0.0125	46.4	22.3	31.3	80.2	12.7	7.1
Cube powder 5% RC, 4 lb., skim-milk powder 2 lb.	0.025	47.5	24.5	28.0	81.2	13.4	5.4
Check		8.4	29.8	61.8	27.4	43.2	29.4

[1] Prepared from *Gesarol A3* dust, product of Geigy & Co., New York.
[2] *Multicide* dust, product of McLaughlin Gormley King Co., Minneapolis, Minn.
[3] Dust containing *Rhothane D3* (dichloro-diphenyl-di h.or ethane), product of Rohm and Haas Co., Philadelphia, Pa.
[4] *Gesarol A20* spray base, product of Geigy & Co., New York.
[5] *Deenol 25EM*, product of E. I. du Pont de Nemours & Co., Wilmington, Del.
[6] Rotenone content.

cube suspension of 0.025 per cent rotenone content. Again the results obtained by a treatment involving the use of DDT in solution seemed particularly promising in view of the reduced strength of DDT required for effectiveness.

TESTS ON THE FALL CROP AGAINST WORMS.—The insecticides tested in the seedbed were also employed in the formulation of mixtures to be applied for control of worms infesting cauliflower. The list of materials included sabadilla powder, ryanex powder and an impregnated pyrethrin powder fortified by the addition of piperonyl cyclohexenone. Pyrethrum and rotenone-containing powders were applied only as dusts for comparative purposes, since spray suspensions of these insecticides have not been effective in worm control under local conditions. Details concerning the formulation and strength of different mixtures are given in tables 3 and 4.

The experiment with dusts was carried out on 20 rows of cauliflower, which for purposes of plot replication were divided transversely into six short tiers. Each treatment occurred once in a systematic series within each tier. The position of the series in each tier was shifted in an attempt to offset variable influences other than that due to treatment. Each tier was 36 feet in length, and plots averaged 24 plants. The experimental area for spray tests consisted of seven rows divided into eight sections or tiers. Each treatment was represented by five replicated plots. The insecticidal mixtures were applied by hand machines.

The period of experimentation extended from July 18, when plants were set out, to October 1, when plants were commenc-

Table 2.—Progress of worm infestation.

DATE EXAMINED	PLANTS	LEAVES PER PLANT	*P. rapae*		*A. brassicae*		*P. maculipennis*	
			Average number per plant					
			Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
July 31	72	3– 7	1.7	0.79	0.53	0.68	0.24	0.32
Aug. 14	60	7–12	0.3	0.46	1.17	1.48	0.13	0.61
Sept. 13	28	24–29	2.18	1.14	11.25	6.0	0.04	2.15

ing to head and were ready to tie. An attempt was made to gauge the progress of worm infestation by noting on three occasions the number of eggs and larvae of different species on plants in check plots. These data are summarized in Table 2.

This information would tend to indicate a fairly heavy infestation of worms, in which *Autographa brassicae* was most in evidence. However its potentials for actual damage were considerably curbed owing to the fact that on each occasion a large proportion of the larvae was composed of very young forms. On July 31 the records show that 94.7 per cent of the larvae of *Pieris rapae* were in the early instars, 97.9 per cent in the case of *A. brassicae*, and 61.9 per cent with *Plutella maculipennis*. On August 14 the proportions were 71.4, 83.1 and 38.8 per cent respectively for these three species, and on September 13, they were 50.0, 69.6 and 16.9 per cent. The greater amount of feeding injury occurred during September as a larger proportion of the larvae attained fuller growth.

Applications of insecticides were made on August 8, August 28 and again on September 20 for dusts and on September 24 for sprays. A rather long interval between applications was permitted owing to the fact that there was little or no serious injury present in plots treated with DDT mixtures. It was evident however that intervals of such length were indirectly an important reason for the occurrence of much of the worm injury in plots not treated with DDT mixtures.

The rates for successive applications of different treatments averaged the equivalent of 26.5, 30.5 and 30 pounds per acre respectively for dusts, and 95, 171.5 and 180 gallons per acre respectively for sprays.

The degree of effectiveness exhibited by different treatments in worm control was determined mainly on the basis of the extent of foliage injury on each plant at the close of the experiment. Four grades were used to denote such injuries, namely, trace, slight, moderate and severe, the two latter groups representing injuries that would usually adversely affect the market value of the produce. These data are summarized in tables 3 and 4.

In general it was evident that DDT dusts were highly effective in worm control at all strengths tested, even when used at less than 1 per cent DDT strength. In the latter case there was apparently

Table 3.—Effectiveness of dusts containing DDT, pyrethrum, cube, sabadilla or *Ryanex* for control of cauliflower worms as indicated by the comparative extent of foliage injury.

Dust Mixtures Proportions by Weight	Per Cent Active Ingredients	Percentage Number of Plants Degrees of Plant Injury			
		Trace	Slight	Moderate	Severe
DDT–talc[1]	3	100.0	0	0	0
DDT–talc	2	100.0	0	0	0
DDT–talc	1	96.6	3.4	0	0
DDT–talc	0.5	94.8	5.2	0	0
Impregnated inert, less than 1% DDT		94.8	5.2	0	0
DDD–talc	2	82.9	16.3	0.8	0
Pyrethrum powder 0.8% PC,[5] *Celite*, talc, 55-10-35	0.44	32.1	54.5	13.4	0
Impregnated exhausted pyrethrum 0.5% PC, *Celite*, talc, 60-10-30	0.3	54.8	42.9	1.5	0.8
Impregnated inert 0.4% PC[2]—piperonyl cyclohexenone 2.5%, *Celite*, talc, 40-10-50	0.16 1.0	25.9	49.6	22.9	1.6
Impregnated inert 0.4% PC—piperonyl cyclohexenone 2.5%, *Celite*, talc, 20-10-70	0.08 0.5	12.8	42.9	42.9	1.4
Cube powder 5% *RC*, *Celite*, talc, 15-10-75	0.75	40.1	48.2	10.2	1.5
Sabadilla, hydrated lime, exhausted pyrethrum, 50-25-25		57.3	33.8	8.1	0.8
Sabadilla, exhausted pyrethrum,[3] 20-80		71.3	27.9	0.8	0
Ryanex,[4] *Celite*, talc, 50-10-40		36.0	50.7	13.3	0
Ryanex, *Celite*, talc, 30-10-60		20.4	53.3	21.9	4.4
Check		31.8	43.9	16.6	7.7

[1] Including admixtures of *Deenate 25W*, product of E. I. du Pont de Nemours & Co., Wilmington, Del.
[2] *P.C.H. 160* dust base, product of Dodge & Olcott Inc., New York.
[3] Products of John Powell Inc., New York.
[4] Product of Merck & Co., Rahway, N. J.
[5] Pyrethrin content

Table 4.—Effectiveness of DDT sprays for control of cauliflower worms as indicated by the comparative extent of foliage injury.

Spray Mixtures Amounts per 100 Gallons	Approximate Per Cent DDT	Percentage Plants with Foliage Injury			
		Trace	Slight	Moderate	Severe
Wettable powder 25% DDT,[1] 3 lb. *Soyspra A* 2 lb.	0.094	86.7	13.3	0	0
Wettable powder 25% DDT, 1.5 lb. *Soyspra A* 2 lb.	0.047	72.2	27.8	0	0
Wettable powder 25% DDT, 0.75 lb. *Soyspra A* 2 lb.	0.0235	48.8	45.3	5.9	0
Oil emulsion 25% DDT,[2] 1 pint	0.0312	77.2	21.6	1.2	0
Oil emulsion 25% DDT, 0.5 pint	0.0156	58.6	40.2	1.2	0
Oil emulsion 25% DDT, 0.4 pint	0.0125	53.6	44.7	1.7	0
Ryanex 6 lb., *Soyspra A* 2 lb.		3.2	32.8	53.6	10.4
Ryanex 4 lb., *Soyspra A* 2 lb.		1.6	34.3	49.2	14.9
Check		0	20.3	47.8	31.9

[1] *Deenate 25W*, [2] *Deenol 25EM*, products of E. I. du Pont de Nemours & Co., Wilmington, Del.

little if any difference in results between dusts prepared from finely ground powders containing DDT and those from inert powders impregnated with a solution of DDT. A dust containing 2 per cent dichloro-diphenyl-dichloroethane (DDD) was slightly less effective than dusts containing technical DDT, dichloro-diphenyl-trichloroethane.

The remaining dust mixtures under the circumstances were significantly less effective than those containing DDT. It was felt that in general this difference in results was chiefly due to the shorter period in which the active ingredients of these insecticides remained effective for purposes of plant protection as compared to DDT. In previous field tests with pyrethrum and rotenone mixtures on Long Island the average interval between applications had normally not exceeded two weeks (Huckett 1940). The lengthening of intervals to three weeks or longer in the current series was done solely in deference to conditions existing in DDT plots. Despite this handicap it may be pertinent to note that a high proportion of plants dusted with a mixture containing 20 per cent sabadilla powder was placed in grades denoting less serious degrees of feeding injury. In contrast plants treated with a mixture containing 50 per cent sabadilla powder were less effectively protected. Data from plots treated with mixtures containing ground pyrethrum flowers diluted to 0.44 per cent pyrethrin strength in the finished dust, or of cube root diluted to 0.75 per cent rotenone strength, indicated that 11 to 13 per cent of plants had received feeding injuries of a more serious nature. In the case however of an impregnated type of pyrethrum mixture diluted to 0.3 per cent pyrethrin strength in the finished dust the results from treatment were only slightly inferior to those obtained in plots dusted with a 20 per cent sabadilla mixture. Plots dusted with impregnated pyrethrin dusts of less than 0.2 per cent pyrethrin content supplemented by the addition of piperonyl cyclohexenone were little benefited by treatment under such circumstances. Applications of a dust containing 50 per cent *Ryanex* powder yielded results comparable to those obtained with dusts containing ground pyrethrum flowers or cube root.

In the case of sprays it was again evident that DDT mixtures were highly effective in worm control. The slight differences in results between sprays of differing DDT strength lay chiefly between categories denoting the lighter degrees of foliage injury. In this respect it was evident that the higher the DDT strength of spray, other factors being equal, the greater the degree of effectiveness attained. While these satisfactory results were obtained with sprays to which DDT had been added as a suspension by means of a wettable powder or as a solution dissolved in an emulsifying agent, it was evident nevertheless that a greater degree of effectiveness was attainable at lower DDT strengths with the latter type of spray than with the former. The significance of reduced strengths, other factors considered, is self-evident in an investigation dealing with an insecticide that may leave harmful residues on the marketed product in excess of the legal tolerance.

SUMMARY.—DDT dusts and sprays were applied to the cauliflower seedbed for control of *Myzus persicae* and *Thrips tabaci* in comparison with treatments containing an analogue of DDT, dichlorodiphenyl - dichloroethane (DDD), and with those having cube powder. DDT dusts of 2, 1 and less than 1 per cent DDT strength tended to be slightly more effective than a cube dust of 0.5 per cent rotenone content. A dust containing 2 per cent DDD was slightly less effective. Sprays containing DDT in solution-emulsion form at strengths of 0.025 and 0.0125 per cent DDT were fully as effective as sprays containing a suspension of cube powder at 0.025 per cent rotenone strength. Nearly comparable results were obtained with a spray containing a suspension of DDT in powder form at a strength of 0.05 per cent DDT, but at greater dilutions the results were less satisfactory.

DDT dusts and sprays were also applied to the fall crop of cauliflower for control of *Pieris rapae*, *Autographa brassicae* and *Plutella maculipennis* in comparison with treatments containing pyrethrum, cube, sabadilla and *Ryanex* powders respectively, as well as with a dust containing dichloro-diphenyl-dichloroethane (DDD). Treatments were applied three times during the period August 8 to September 24 inclusive at intervals that averaged slightly longer than three weeks. In these tests DDT dusts ranging in strength from less than 1 per cent to 3 per cent DDT were highly effective in worm control. A dust containing 2 per cent DDD was slightly less effective. The remaining dust mixtures, which contained insecticides of plant origin, such as pyrethrum, cube root, sabadilla seed and *Ryanex*, were significantly less satisfactory. It is felt that the reason for such inferior results was chiefly the extended intervals between applications, which, while applicable to DDT treatments, were too long for the effective employment of dusts containing pyrethrins and rotenone. Despite this handicap plots dusted with a mixture containing 20 per cent sabadilla powder gave evidence of promising results.

DDT sprays were also effective for purposes of worm control. The sprays consisted of suspensions of a wettable powder containing 25 per cent DDT, and of mixtures of an oil emulsion possessing 25 per cent DDT in solution. Sprays containing 1.5 or 3 pounds of the above powder in 100 gallons of water, at strengths of 0.047 and 0.094 per cent DDT respectively, and 1 pint of the emulsion in 100 gallons of water, at a spray strength of approximately 0.0312 per cent DDT, were slightly more effective than sprays of lower DDT content. These results with sprays are of particular interest locally in that heretofore sprays containtaining suspensions of pyrethrum or rotenone-containing powders have not been effective for control of worms on cauliflower.—1-9-46.

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Cameron Siddall, formerly engaged in Extension work in Entomology in Texas where he was connected with the Agricultural and Mechanical College at State College, and who served for more than three years in the Army Sanitary Corps, has accepted a position as Acting Manager of Cotton Poisons, Inc., at Bryan, Texas. This firm is a subsidiary of the Pennsylvania Salt Co., of Philadelphia,

Control of Aphids on Potatoes in Northeastern Maine[1]

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Because of their transmission of virus diseases, particularly leaf roll, aphids[3] have been recognized as the most serious pests attacking potatoes in northeastern Maine. In experiments conducted during the five seasons 1940 to 1944, as reported by Bronson (1945), the most effective materials were sprays or dusts containing ground derris powder, and in 1944 promisng results were obtained with dusts containing DDT. Treatments with these materials reduced the number of aphids, but in Bronson's experiments they did not reduce the spread of leaf roll. However, the insecticidal treatments increased considerably the yield of potatoes over those of the untreated checks. Limited tests in 1944 with aerosols containing DDT showed high toxicity to aphids infesting potato (Smith *et al.* 1945).

Experiments in 1945 were conducted at Houlton, Maine, with various formulations of DDT, derris, nicotine, and benzene hexachloride, applied with equipment being used commercially for field spraying or with experimental machines designed for field use. The objectives were (1) to compare the efficiency of these materials, when combined with fungicides for late blight, against aphids and other potato insects, and (2) to obtain information on the possible effects of aphicides in relation to plant tolerance, crop yields, and transmission of leaf roll. The experiments were conducted on seven farms, on plots ranging in size from 3/4 acre to 5 acres, except in experiment 1, in which the plots contained 1/8 acre.

Materials and Methods.—*Equipment.* For the application of sprays in experiment 1, and for certain treatments in the other experiments, the tractor-mounted spray unit featured a fixed boom covering six rows. The unit was designed and largely built by J. W. Slosser, of the U. S. Soil Conservation Service. Each row received spray from four nozzles—two directed downward at an angle from above and two directed upward from near the soil surface, where they were attached, between diverging vine-lifter rods, to a shoe riding on the soil surface. Approximately 100 gallons of spray at 225 pounds' pressure was applied per acre.

For application of the aerosols a tank of the solution was mounted on the tractor and led through copper tubing to nozzles attached to the *Slosser* spray boom. These nozzles were mounted in approximately the same position on the boom as the regular spray nozzles (Goodhue *et al.* 1945).

Tractor sprayers, drawn either by a tractor or by horses, were used on farms 1, 2, and 3. The booms on these sprayers were fitted with two nozzles per row and applied about 75 gallons per acre at 375 pounds' pressure. On farms 4 to 7, inclusive, 100 gallons per acre at 400 pounds' pressure was applied with tractor-mounted sprayers equipped with booms fitted with three nozzles per row. The dusts were applied at the rate of 35 pounds per acre by means of a tractor-mounted six-row duster operated from the power take-off.

The concentrated spray mixtures were applied at the rate of 7 gallons per acre by means of experimental equipment designed and built especially for use in control of the white-fringed beetle. This machine discharged the mixture through a single oscillating nozzle by a centrifugal pump operating at 5 pounds' pressure. An air blast from a high-velocity fan further broke up and distributed the spray.

Insecticides Used. Technical-grade DDT was used in the preparation of dusts, spray suspensions, and emulsions, while the aerosol-grade DDT, a more highly refined product, was used in the preparation of the aerosols. The various DDT mixtures were prepared as follows:

A commercial dust containing 10 per cent of DDT in pyrophyllite was mixed with tribasic copper sulfate and talc to make a final mixture containing 5 per cent of DDT and 7 per cent of metallic copper.

[1] Results of a cooperative project between the Bureau of Entomology and Plant Quarantine and the Maine Agricultural Experiment Station.

[2] The authors are indebted to W. A. Shands, of the Bureau of Entomology and Plant Quarantine, and to Fay Fong Yee and Roger M. Cobb, of the Maine Agricultural Experiment Station, for assistance in these investigations. L. D. Goodhue, of the Bureau of Entomology and Plant Quarantine, prepared the aerosol solutions and rendered advice in the construction of the aerosol equipment.

[3] The buckthorn aphid, *Aphis abbreviata* Patch; the green peach aphid, *Myzus persicae* (Sulz.); the potato aphid, *Macrosiphum solanifolii* (Ashm.); and the foxglove aphid, *Myzus pseudosolani* (Theob.).

The spray suspension was prepared by adding a commercial water-dispersible powder containing 40 per cent of DDT or a laboratory product containing 50 per cent each of DDT and kaolin to the sprays to give a dosage of either 0.8 pound or 2 pounds of DDT per 100 gallons.

Emulsion A was prepared by dissolving 0.5 pound of DDT in 390 ml. of a proprietary mixture of di- and trimethylnaphthalenes and adding 20 ml. of a proprietary emulsifier consisting of polyethylene glycol monoisooctyl phenyl ether. The quantity of stock emulsion thus prepared was used with sufficient water or fungicide spray to make 100 gallons of conventional spray or 7 gallons of concentrated spray.

Emulsion B was the same as above, except that polyethylene glycol 400 monooleate was used as the emulsifier.

Emulsion C was the same as emulsion A, except that 395 ml. of a proprietary mixture of undesignated methylated naphthalenes was substituted for the mixture of di- and tri-methylnaphthalenes.

Emulsion D was prepared by dissolving 0.5 pound of DDT in 450 ml. of xylene and adding 20 ml. of polyethylene glycol monoisocotyl phenyl ether. This quantity of stock emulsion was used with sufficient bordeaux mixture to make 100 gallons of spray.

The aerosol solution contained 5 per cent of DDT, 5 per cent of cyclohexanone, 5 per cent of a mixture of di- and tri-methylnaphthalenes, 35 per cent of acetone, and 50 per cent of methyl chloride. A separate application of a tribasic copper sulfate spray was made just before each aerosol treatment.

The derris spray contained 3 pounds of ground derris root (4 per cent rotenone), 0.5 pint of a proprietary wetting agent consisting of a 30 per cent solution of decylbenzene sodium sulfonate in water, and 1 pint of soybean oil per 100 gallons of spray mixture. The derris root was first made into a paste with the wetting agent and a small quantity of water, after which the soybean oil was added.

The zinc nicotinyl fluosilicate dust was prepared by mixing 14 pounds of tribasic copper sulfate, 30 pounds of hydrated lime, and 49 pounds of talc with 7 pounds of zinc nicotinyl fluosilicate (33 per cent nicotine). This mixture contains 2.3 per cent of nicotine and 7 per cent of metallic copper.

The nicotine spray was prepared by adding 1 quart of nicotine sulfate solution (40 per cent nicotine) to 100 gallons of bordeaux mixture.

A commercial mixture containing 20 per cent of benzene hexachloride was further diluted with talc to give a product containing 5 per cent of the active ingredient.

Fungicides Used. The bordeaux mixture contained 8 pounds of copper sulfate and 8 pounds of hydrated lime per 100 gallons of spray. The dithiocarbamate mixture contained 2 quarts of disodium ethylene bisdithiocarbamate, 1 pound of zinc sulfate, and 0.5 pound of hydrated lime per 100 gallons of spray. The tribasic copper sulfate containing 52 per cent of metallic copper was used at the rate of 4 pounds per 100 gallons of conventional spray or per 7 gallons of concentrated spray.

Data Recorded. To determine the extent of leaf roll infection in treated and untreated plots, tuber samples were taken at intervals. These will be planted and the new growth will be observed for symptoms of leaf roll.

Yields taken at harvest time from most of the plots were based on samples consisting of 800 to 1400 feet of row.

Aphid-population records were based on the number of apterous individuals of each species occurring on 1 top, 1 middle, and 1 bottom leaf of each of 25 plants taken at random in each plot.

EXPERIMENTS AND RESULTS.—*Experiment 1.* The efficiency of several DDT preparations was compared by making five applications at approximately 1-week intervals between July 6 and August 9 to four replicated plots for each treatment. Records on aphid populations were taken after the third and fourth applications, on July 28 and August 4, respectively; but, since the relative results on the two dates were approximately the same, only data from the fourth count are included in the table. The plots were harvested early for seed, and there was not sufficient damage from aphid feeding up to harvesttime to cause a reduction in yield.

The buckthorn aphid was the most abundant species present. As shown in table 1, the aerosol was the most effective, but the emulsion and the suspension con-

Table 1.—Control of aphids on potatoes with four applications of DDT insecticides mixed with the fungicide tribasic copper sulfate. Houlton, Maine, 1945. Experiment 1, four replicates.

METHOD OF APPLYING DDT	POUNDS OF DDT PER ACRE PER APPLICATION	NUMBER OF APHIDS AFTER FOUR APPLICATIONS					PER CENT CONTROL
		Buckthorn Aphid	Green Peach Aphid	Potato Aphid	Foxglove Aphid	All Species[1]	
Aerosol[2]	1.0	24	18	26	0	68	99
Suspension	2.0	167	5	48	3	223	98
Emulsion A (di- and trimethylnaphthalenes)	.5	183	10	68	4	265	98
Dust	1.8	1,278	153	92	21	1,544	86
Checks:							
Derris	—	1,494	368	405	19	2,286	80
Fungicide only[3]	—	6,732	2,998	1,561	246	11,537	—

[1] A difference of 1,268 required for significance at odds of 19:1.
[2] The aerosol was applied after the fungicide, not mixed with it.
[3] Calcium arsenate, 4 pounds per 100 gallons of spray, was used in the first application to control the Colorado potato beetle.

taining 0.5 pound and 2 pounds of DDT, respectively, per 100 gallons were not significantly less effective. The DDT dust and the derris spray were less effective. In two of the replicates treated with DDT dust the reduction in number of aphids was equal to that in the other DDT treatments, but in the two remaining replicates the control was poor. This may have been due to mechanical difficulties in the operation of the duster during two applications.

Experiment 2. It was considered advisable to obtain as much information as possible on the effectiveness of DDT mixtures under commercial conditions when applied by the grower with different types of equipment. Because of variations in the effectiveness of application, soil fertility, and intensity of aphid infestation, no attempt was made to detect small differences in either aphid infestation or final yield. The purpose was to determine whether the use of these mixtures under actual farm conditions would result in satisfactory control of aphids and other insects and in substantial increases in yield. Some of the differences in yield are doubtless due to infestations of flea beetles, which were present in all plots. It was impossible to determine just how much of the yield reduction in the check plots was caused by aphid feeding and how much by the feeding of flea beetles. The results of these tests with Katahdin potatoes are presented in table 2.

It is evident that the sprays applied with the tractor sprayers at a higher gallonage and pressure, with three nozzles per row, were more uniformly effective in reducing the aphid populations than were the two-nozzle traction sprayers. In general there appeared to be a positive relationship between the intensity of infestation and the yield. However, notwithstanding the comparatively low and variable reduction in aphid populations, very substantial yield increases were obtained from plots treated with the traction equipment. It should be remembered that these increases were the result of regular applications throughout the season, and if fewer applications had been made the differences in effectiveness between the two types of equipment might have been more pronounced. The tractor-mounted sprayers appeared to be more satisfactory for the application of insecticides than were the traction sprayers.

Experiment 3. A number of insecticides were applied with different types of equipment to a field of Katahdin potatoes. The purpose was to determine whether two thorough applications after the aphid infestation had become well established would prevent aphid damage. Flea beetles were numerous in the field, and therefore yield records reflect both aphid and flea beetle damage. The results of these tests are given in table 3. Most of the infestation counts made after the first application indicated a very high percentage of aphid control and demonstrated that infestations could be substantially reduced when adequate equipment was employed. The single application of tribasic copper sulfate dust containing 5 per cent of DDT resulted in a 99 per cent reduction of aphids, and this dust was the most effective material used. The benzene hexachloride dust also proved to be very

Table 2.—Control of aphids on potatoes with DDT insecticides mixed with bordeaux and applied under commercial conditions to single plots. Houlton, Maine. Experiment 2.

Farm No.	Method of Applying DDT	Pounds of DDT per Acre per Application	Number of Applications		Number of Aphids Present					Per Cent Aphid Control	Yield per Acre (Bushels)	Per-Cent Increase in Yield
			Before Aphid Counts	Total	Buckthorn Aphid	Green Peach Aphid	Potato Aphid	Foxglove Aphid	All Species			
	With traction sprayer having two nozzles per row											
1	Suspension	0.6	3	3	1,018	378	739	20	2,155	70	505	12
	Emulsion B (di- and trimethylnaphthalenes)	.4	5	7	454	168	329	3	954	87	491	9
	Check (bordeaux only)	—	5	7	1,199	2,310	1,766	1,816	7,091	—	451	—
2	Suspension	.6	3	5	146	853	2,908	0	3,907	37	439	16
		1.5	3	5	47	547	1,403	1	1,998	68	397	5
	Emulsion D (xylene)	.4	3	5	211	245	1,245	0	1,701	73	470	24
	Check (bordeaux only)	—	3	5	10	1,196	4,998	0	6,204	—	378	—
3	Suspension	.6	5	7	251	255	425	30	961	27	457	18
	Emulsion C (methylated naphthalene)	.4	3	5	63	57	293	0	413	45	443	14
	Check (bordeaux only)	—	5	7	142	272	285	57	756	—	387	—
	With tractor sprayer having three nozzles per row											
4	Suspension	.8	3	6	240	320	679	4	1,243	70	499	1
	Emulsion A (di- and trimethylnaphthalenes)	.5	2	5	62	419	652	2	1,135	73	573	16
	Check (bordeaux only)	—	3	6	2,808	433	896	10	4,147	—	493	—
5	Suspension	.8	5	6	1,220	327	697	8	2,252	80	494	39
	Emulsion A	.5	5	6	138	322	478	2	940	92	428	20
	Check (bordeaux only)	—	5	6	10,482	558	304	69	11,413	—	357	—
6	Emulsion A[1]	.5	4	5	51	19	89	35	194	98	—	—
	Emulsion A	.5	4	5	150	32	232	18	432	97	—	—
	Suspension	.8	4	5	951	168	685	311	2,115	86	—	—
	Checks:											
	Nicotine sulfate plus bordeaux mixture	—	4	4	32	164	114	148	458	97	—	—
	Bordeaux only	—	4	5	9,971	2,195	1,590	1,543	15,299	—	—	—
	Dithiocarbamate[1] mixture only as a fungicide	—	4	5	6,128	544	569	1,125	8,366	—	—	—

[1] The dithiocarbamate mixture was used as the fungicide instead of bordeaux mixture.

effective, resulting in a reduction of 97 per cent. Both of these dusts were more effective against the potato aphid than were the sprays. The zinc and nicotinyl fluosilicate dust mixture, the DDT aerosol, and the DDT emulsion also proved to be very effective, although the aphid reduction was substantially lower than with the DDT and benzene hexachloride dusts. The DDT emulsion was not satisfactory, however, when applied as a concentrated spray. The Slosser boom sprayer was more efficient in applying the emulsion than was one of the best three-nozzle tractor sprayers in general use in the area.

The 5 per cent DDT-tribasic copper sulfate dust, which proved to be most effective in reducing the aphid populations, was also most effective on the basis of yield, which was 639 bushels per acre, or an increase of 73 per cent over the check plot and nearly 100 bushels per acre above that of the next best treatment. In general the aphid control by the different treatments was reflected in the yields. The DDT aerosol, however, did not result in so great an increase in yield as did the emulsion applied by the Slosser sprayer, although the percentage of aphid control was practically the same. At least part of this difference may have been due to mechanical damage to the crop, since it was necessary to drive through the plot twice to apply both the aerosol and the fungicide.

There was actually a small decrease in yield in the plot treated with the concentrated spray emulsion. This plot was located near a fence row and on very light soil, which suffered more from drought than did other parts of the field. Had soil conditions been uniform, an increase in yield would have been expected. The control of flea beetles in this plot was adequate, but the control of aphids was poor.

Experiment 4. A test was made on Chippewa potatoes near Oxbow, Maine, where the foxglove aphid was the predominant species on which to compare aphid susceptibility to DDT and to derris. Applications of DDT in emulsion C and also of derris spray were made with a three-nozzle tractor sprayer to 1-acre plots on August 5. Counts made before

Table 3.—Control of aphids on potatoes after the first of two applications of insecticides mixed with fungicides and applied with different equipment. Houlton, Maine, 1945. Experiment 3, single plots. (Counts made on 75 leaves.)

Insecticide	Fungicide	Pounds of DDT Applied per Acre	Number of Aphids after First Application					Per Cent Aphid Control	Yield per Acre (Bushels)	Per Cent Increase in Yield
			Buckthorn Aphid	Green Peach Aphid	Potato Aphid	Foxglove Aphid	All Species			
DDT dust mixture	Tribasic copper sulfate	1.8	35	9	18	9	71	99	639	73
DDT emulsion A applied by:										
Slosser sprayer	Bordeaux	.5	1031	41	290	27	1389	90	547	48
Tractor sprayer	Bordeaux	.5	3270	465	275	129	4139	71	509	38
Special equipment as concentrated spray	Bordeaux	.5	3945	1887	330	870	7032	50	365	−1
DDT aerosol	Bordeaux applied before insecticide only	1.0	890	318	270	47	1462	90	458	24
Benzene hexachloride dust mixture	Bordeaux applied before insecticide only	[1]1.8	393	31	55	9	488	97	—	—
Zinc nicotinyl fluosilicate dust mixture	Tribasic copper sulfate	[2]1.8	742	202	681	739	2364	83	510	38
Check (2 plots, no insecticide)	Bordeaux	—	8706	2324	1468	1593	14091	—	370	—

[1] Pounds of active ingredient.
[2] Pounds of nicotine.

treatment showed that the infestations in the check and DDT-emulsion plots were similar and the infestation in the derris plot was somewhat lower. The results of counts after one treatment, given in table 4, show that the foxglove aphid is about as susceptible to DDT as the other species and that all species are more susceptible to DDT than to derris.

DISCUSSION.—When infestation counts were made, both wingless and winged aphids were recorded in all cases, but the numbers of winged aphids were fairly uniform, and are therefore not given in the tables. The relatively large numbers of winged aphids in the treated plots seemed to be due partly to the continuous movement to and from the plots. There was no indication that the presence of DDT residues on the plants was a factor in reducing the number of these dispersal forms or in preventing their establishment on the treated plots. Tubers from treated and untreated plots were grown in Florida and observed for evidence of reafroll in the new generation foliage. Because the percentage of infected plants was higher in treated lots than in checks it was evident that the DDT residues had not affected the viruliferous aphids sufficiently to prevent infection.

The apparatus for applying concentrated sprays did not prove satisfactory for use in aphid control. The distribution of the spray mixture on the foliage of potatoes on the outside of the hilled rows was inadequate.

Although no counts were made of the flea beetles and Colorado potato beetles killed in these experiments, observations substantiated the results reported by Gyrisko *et al.* (1945). All DDT preparations employed were very effective against these beetles.

There was no evidence of plant injury by any of the DDT formulations included in these experiments. In other plantings of potatoes taller growth and increased

Table 4.—Control of aphids on potatoes with insecticides (DDT and derris) in bordeaux mixture. Oxbow, Maine, 1945. Experiment 4.

Treatment	Number of Aphids after One Application					Per Cent Control	
	Buckthorn Aphid	Green Peach Aphid	Potato Aphid	Foxglove Aphid	All Species	All Species	Foxglove Aphid
DDT in emulsion C	184	69	90	821	1164	85	86
Derris spray	440	157	413	2068	3078	61	64
Check (bordeaux only)	651	483	917	5808	7859	—	—

inflorescence, particularly of the Sebago and Green Mountain varieties, were evident where the potatoes were treated with DDT. All treated plots remained green much later in the season, owing to control of flea beetles as well as to reduction of aphid populations. The plants in many of the check plots became stunted and flaccid and were coated with honeydew.

Addition of DDT suspension to bordeaux mixture intensified the bluish-white deposit on the foliage as compared with the bordeaux checks. The addition of DDT emulsions, however, reduced this deposit and the foliage was deeper green. The addition of DDT to fungicide dusts or sprays caused no evident reduction of the fungicidal action, since control of late blight appeared to be good.

At the temperatures prevailing during the summer the DDT in all emulsions remained in solution, but if exposed to lower temperatures or stored over winter it may crystallize out. In other experiments where 450 ml. of the solvents was used per 0.5 pound of DDT and 20 ml. of the emulsifier in preparing the stock emulsions, the crystals formed by depressing the temperatures below freezing redissolved at normal summer temperatures.

SUMMARY.—During 1945 field experiments were conducted in northeastern Maine to determine the effectiveness of various insecticides for the control of aphids on potatoes, when used with fungicides applied for the control of late blight disease.

DDT applied as an emulsion, an aerosol, a dust mixture, or a suspension was effective in reducing populations of the buckthorn aphid, *Aphis abbreviata* Patch; the green peach aphid, *Myzus persicae* (Sulz.); the potato aphid, *Macrosiphum solanifolii* (Ashm.); and the foxglove aphid, *Myzus pseudosolani* (Theob.); and in increasing the yield of potatoes. Although there was a tendency for the dust mixture to be more effective than the sprays and the aerosol, greater quantities of DDT per acre were used in the dust mixture and the suspension than in the emulsions and the aerosol.

Tractor-mounted sprayers applying 100 gallons per acre reduced the aphids more satisfactorily than did traction sprayers delivering 65 to 75 gallons per acre. When a four-nozzle sprayer equipped with vine lifters was used, the kill of aphids was slightly greater than that obtained with a standard three-nozzle sprayer. The use of a concentrated spray applicator resulted in poor aphid control.

All DDT treatments were highly effective against Colorado potato beetles and potato flea beetles.

All treated plots remained green much later in the season than did untreated plots, owing to control of flea beetles as well as to reduction in aphid populations. Viruliferous dispersal forms of winded aphids were attracted to the green treated foliage and resulted in higher percentages of leaf roll in harvested tubers than in tubers from check plots.

A zinc nicotinyl fluosilicate dust and a nicotine sulfate spray were effective aphicides. A derris spray was inferior to DDT treatments. Benzene hexachloride dust mixture was very effective against all species of aphids, as well as flea beetles. —1-9-46.

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Dr. Robert L. Usinger, Sanitarian (R), U. S. Public Health Service, is to be released from the service on May 1, 1946, and will return to the University of California where he may be addressed 112 Agriculture Hall, Berkeley.

DDT as a Control for the Pea Aphid[1]

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During the past ten years or more those agencies responsible for the control of pea aphid have spent a great deal of time and effort in the working out of insecticides and insecticide combinations adapted to this problem, as well as in the development of special equipment for applying them.

As a result of this activity truly remarkable progress has been made in this relatively short period, but while recognizing all this it must be admitted that, from the standpoint of those directly charged with the practical application of control measures in the field, the methods and materials that are now commonly available for use against the pea aphid still leave much to be desired, due either to lack of consistent performance on the part of the insecticides or to the available equipment not proving adequate for the exacting work demanded of it.

With this situation in mind there appeared to be every reason for giving the new insecticide DDT a thorough trial in the field of pea aphid control even though the early performance of this material suggested that it was not likely to prove an outstanding aphicide for general use.

The following statement summarizes our experience during the past season with a number of DDT dust formulations, and also where DDT was used in the form of concentrated as well as in conventional type sprays.

The aphid counts were in all cases based on the number of insects taken in 10 strokes of a standard beating net, the general technique followed in making the counts having already been described in an earlier number of the JOURNAL (Glasgow 1939). In the case of the dust series (Table 1) each record is based on the average of three such counts taken at widely separated points in the same plot. Most of the dusts used in these tests were mixed shortly before the time of application. The dusts were in most cases made up from a standard 40 per cent DDT dust[2] concentrate. In compounding the dusts the DDT concentrate together with a small amount of the diluent and any supplement that might be used was thoroughly premixed by hand after which the resulting mass was added to the bulk of the diluent—*Pyrax ABB* in most cases—and the final mixing completed in a standard *Bean Self-Mixing Duster*. With but few exceptions the DDT dusts prepared in this way were quite satisfactory from the standpoint of physical make-up.

Applications in the field were made by means of a regular motorized Bean duster equipped for pea aphid work with a 60 foot trailer. The machine was driven through the field at the rate of two piles per hour each plot being approximately a half acre in size. The plots in this experiment were long and narrow, and were arranged in a continuous series from south to north.

Table 1.—Relative efficiency of DDT and rotenone dusts as measured by pea aphid kill.

Insecticide Content of Dust Per Cent	Supplement Used Per Cent	Dosage, Lb. per Acre	Per Cent Kill		
			June 7	June 22	Average
	—DDT and—				
1.0	none	40	56.6	82.8	70.6
1.0	2.0 Mineral oil[1]	36	78.4	85.6	82.2
1.0	2.0 *Velsicol 60*	40	97.4	95.4	96.3
3.0	2.0 Mineral oil	42	96.7	97.1	96.9
3.0	0.5 Nicotine	48	93.9	89.9	91.3
5.0	2.0 Mineral oil	43	98.6	98.2	98.5
	—Rotenone and—				
0.25	none	50	37.1	33.9	35.7
0.25	2.0 Mineral oil	58	39.8	47.9	44.0
0.25	2.0 *Lethane 60*	46	54.2	49.8	52.0
0.25	2.0 *Velsicol 60*	46	34.9	47.6	41.6
0.5	2.0 Mineral oil	60	79.1	72.7	75.7
0.75	1.5 Nicotine	48	87.8	86.2	87.0
1.0	2.0 Mineral oil	47	91.6	79.1	85.0

[1] The mineral oil used was in all cases an S.A.E. 10 Pennsylvania motor oil.

The first and every fifth plot thereafter were left untreated to serve as a check, there being a total of six such checks in this dust series which comprised a total of 24 plots. In figuring the efficiency of the various treatments each group of four dusted plots was governed by the average of the two untreated checks on either side of that particular group.

The aphid population in this field, while fairly uniform, was found to increase progressively from south to north.

The dusts were all applied on May 25,

[1] Journal paper No. 661, N. Y. State Agr. Exp. Station, Geneva, N. Y.

[2] Supplied by the Geigy Co.

the operation starting at about 10 A.M. and being complete at 4:30 the same afternoon. Final counts were made on June 7 and again on June 12.

Two days before the dusts were applied there had been a rain of over a half-inch and at the time the applications were started the ground and the lower part of the plants was distinctly damp. Temperatures during the period of application ranged from 67 to 72 degrees and the wind velocity from 1 to 4 miles per hour. The results of the tests with DDT and rotenone dusts are given in table 1.

It will be noted that the dosages in the case of these dust applications varied considerably for the different formulations, owing largely to the difficulty of accurately calibrating a machine of this type where a number of different dust mixtures are being applied in relatively small amounts. This variation in dosage should naturally be reflected to some extent in the mortality records although no attempt has been made in the table to compensate for this.

Table 2.—Efficiency of DDT in pea aphid control as applied by the Todd Insecticide fog applicator.

Approx. Dosage Lbs. per Acre	Per Cent Aphids Killed at Indicated Distance from Machine				
	Feet				
	10	18	50	100	200
	Thomas Coyne Fiel				
1.5		99.3	93.1	84.1	15.9
	Howard Denton Field				
1.5	98.9	—	78.9	30.5	8.1
3.0	100.0	—	92.6	85.7	26.5
	Clem Davin Field				
1.5	97.3	—	61.4	65.3	none
	Hanna and Wadsworth Field				
1.5	97.5	—	71.9	23.7	28.8
1.5	98.7	—	85.1	59.3	40.5
3.0	100.0	—	85.1	42.8	none
1.5	96.8	—	none	18.7	none

The experiments on which table 1 is based were carried out in a heavily infested alfalfa field having a dense plant growth of from 18 to 20 inches. In our experience alfalfa has proved an exceedingly useful test plant for field studies on pea aphid control. By utilizing alfalfa as a test plant in this way the equivalent of two years' work on the pea aphid can usually be crowded into a single season. Since the aphid invariably builds up on alfalfa several weeks before it does on cannery peas it is generally possible to complete a set of control experiments on alfalfa and assemble the results in time to use these as a guide in planning for a comparable series of experiments on peas by the time the aphid infestation finally develops on that crop.

In this particular experiment the DDT dusts show up to decidedly better advantage than the rotenone, the 5 per cent concentration appearing outstandingly effective while even the 1 per cent dust with the oil supplement, although relatively poor, approached the best of the rotenone series in efficiency.

The mineral oil as a supplement appeared in this series to add appreciably to the effectiveness of the DDT dusts, although this was not particularly striking. When better solvents were used, however, such as xylol, *Velsicol* or benzol the resulting increase in efficiency of the DDT was very much more pronounced and from our experience so far it would appear that the use of solvents as supplements will probably have a much more important application in the case of DDT dusts than they have had with rotenone dusts.

Conventional sprays based on a rate of application of from 150 to 200 gallons to the acre have never seemed to fit well into the pea aphid control program in New York.

Small scale tests with DDT sprays applied on this basis, however, have indicated that solutions of DDT applied as emulsions appear to be appreciably more effective than when simple mechanical suspension of the DDT are used.

Since in the beginning it was felt that relatively heavy dosages of DDT might be required in sprays to control the pea aphid an attempt was made to work out a procedure that would enable the operator to reduce the cost of the finished spray as much as possible. To this end it was found that an effective, economical spray could be prepared by emulsifying a 50 per cent benzol solution of DDT in a weak bordeaux or some other cheap emulsifying agent, following the recognized technique used in making tank mix emulsions in orchard work.

With benzol at approximately 25 cents a gallon and technical grade DDT at 50 cents a pound such a tank mixed spray can be readily prepared even at relatively

high concentrations without the costs becoming prohibitive.

At the rate of 2 pounds of DDT to 100 gallons, sprays prepared in this way have given a satisfactory kill of the pea aphid wherever adequate coverage was secured.

So far, we have not been concerned with reduced dosages of DDT, our main interest being to determine whether DDT could be expected to control the pea aphid even under the most favorable conditions.

FIG. 1.—Machine used to apply aerosols. (Constructed and operated by Birdseye-Snider Div., General Foods Corp.)

Preliminary tests with concentrated sprays using a 15 per cent solution of DDT in a light mineral oil as applied by means of standard 1 gallon an hour oil burner nozzles and a high pressure pump (Fig. 1), at the rate of from 4 to 6 gallons to the acre, gave a relatively high kill of the pea aphid and suggest that in this form DDT may well have a real place in pea aphid control when applied either by ground machine or airplane.

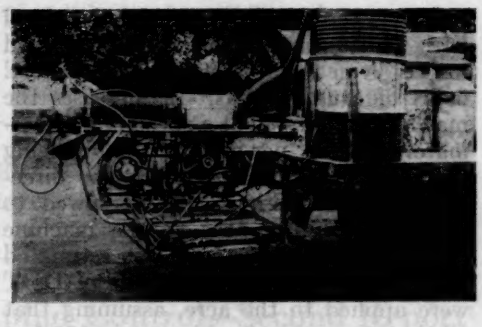

FIG. 2.—An early type of Todd Fog Applicator.

Preliminary tests were also carried out this past season with a 5 per cent solution of DDT in No. 1 fuel oil applied as a fog by means of a recent development in the insecticide field known as the *Todd Insecticide Fog Applicator* (Fig. 2). This is another promising method for applying insecticides such as DDT, essentially in the form of a concentrated oil spray, or aerosol, if one prefers that term.[1]

[1] Equipment for these tests was supplied and operated through the cooperation of Mr. Frank K. Steinrock of the Todd Shipyards Corporation while the DDT was provided through the kindness of Drs. J. A. Evans and H. F. Dietz of the DuPont Chemical Co.

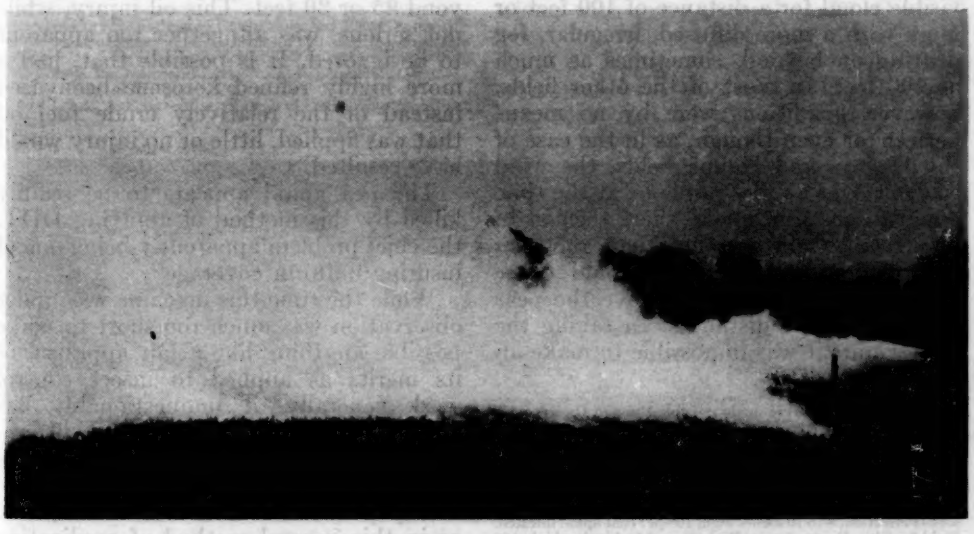

FIG. 3.—Todd Fog Applicator in operation showing how the fog may penetrate through matted pea vines.

The experiments on pea aphid control with the fog applicator were all located in the Avon territory in four commercial fields of cannery peas.[2] In all cases the machine was driven at a speed of approximately 100 feet per minute, the fog being discharged at right angles to the direction of travel (Fig. 3) and allowed to drift through the peas as the machine progressed. At this rate it was estimated that something like 1.5 pounds of DDT were applied to the acre, assuming that all the fog was retained in a strip 100 feet wide, which of course was not always the case. In some plots double this amount was applied by simply going over the same ground twice. In each field a large untreated area of an acre or more was left for comparison.

Applications were made on June 18 and 19 under exceptionally favorable conditions and the final aphid counts were made the afternoon of June 22.

In checking on the results of the work with the fog applicator counts were taken at distances of 10, 50, 100 and 200 feet from the machine except in the case of the Thomas Coyne field where it was necessary to make the first count at 18 instead of 10 feet. Counts were all based on the number of insects taken in 10 strokes of a standard 11-inch beating net equipped with a 26-inch handle.

In the Thomas Coyne field (Fig. 3) the fog held in the peas and carried as a dense visible cloud for a distance of 100 feet or more with a more diffused, irregular, fog drifting on beyond, sometimes as much as 200 feet. In most of the other fields, however, conditions were by no means perfect for even though, as in the case of the Denton and Hanna fields, the wind was not over 2 miles per hour at the time applications were made, there seemed to be irregular air currents that at times and without any warning would cause the fog to rise and drift above the peas for considerable distances. In taking the final counts it was impossible to make allowance for such uneven applications because much of the work was done late in the evening and the areas of continuous fog were not in all cases clearly marked out at the time.

Wherever the dense part of the fog covered the peas as in (Fig. 2) the kill of the aphid was very satisfactory indeed but it should be pointed out that here, as in all types of insecticide application where the material is allowed to drift into or over the crop to be protected, the problem of compensating for unfavorable air currents is a very real one. So far as this particular crop is concerned it is doubtful whether the present method of distribution will prove practical unless some means is developed for confining the fog about the plants to be protected, at least for a time.

As to dosage with the fog applicator there is some indication that 3 pounds may be slightly better than 1.5 but apparently little was gained in these tests by applying the greater quantity and the question of securing uniform coverage is probably much more important than any increase in dosage beyond the 1.5-pound minimum used.

The presence of a film of oil on the treated peas could be detected up to 50 or 60 feet from the machine. Evidence of oil injury to the foliage was quite apparent close to the machine, gradually diminishing until only traces could be found beyond 25 or 30 feet. This oil injury, while not serious, was altogether too apparent to be ignored. It is possible that, had a more highly refined kerosene been used instead of the relatively crude fuel oil that was applied, little or no injury would have resulted.

The pea aphid appears to be readily killed by this method of applying DDT, the chief problem apparently being one of insuring uniform coverage.

While the time this machine was under observation was much too short to make possible anything like a fair appraisal of its merits as applied to insect control work generally, it unquestionably has many attractive features and will undoubtedly prove an important addition to our insect control program.

Any possible weakness in the machine or in this general method of application as well as its true place in insect control

[2] The experiments were made possible through the generous cooperation of officials of the Birdseye-Snider Division of General Foods Corporation in providing the necessary pea acreage and other facilities. The pea fields in which the experiments were located were owned by the following men: Field No. 1—Howard Denton, 12 acres Perfection, plants 8 to 10 inches high, 100 per cent aphid infested. Field No. 2—Hanna and Wadsworth, 12 acres Perfection, 8 to 10 inches high, 100 per cent aphid infested. Field 3—Clem Davin, 5 acres Perfection, 2 to 4 inches high, 100 per cent aphid infested. Field 4—Thomas Coyne, 6 acres Asgrow Pride plants 10 to 12 inches high, 60 per cent infested.

can only be determined by further carefully controlled field tests directed against specific insect problems.

Our experience so far with DDT as applied in both dusts and sprays indicates that it has real possibilities for use against the pea aphid and further studies may well show it to be one of our most important insecticides for use against this particular aphid.—1-9-46.

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Insecticidal Aerosols for Pea Aphid Control—Second Report[1]

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Because of favorable results obtained in the control of the pea aphid, *Macrosiphum pisi* (Kalt.), with insecticidal aerosols in small-plot experiments during 1944 (Ditman *et al.* 1945), the usefulness of aerosols was further investigated in 1945 on a more extensive scale. A power-drawn dispenser similar to the hand-drawn device used in the previous experiments was built for application to commercial acreage of peas. Over 100 acres were treated in Maryland during the season. The field experiments were planned and carried out to determine the efficiency of the dispensing equipment and the effectiveness of the applications under various weather conditions, to obtain information on the dosages under varying speeds of operation, and to improve and reduce the cost of the aerosol solutions given in table 1.

DISPENSING EQUIPMENT.—An aerosol dispenser was constructed which consisted of a center 6-foot section and a 9-foot wing on each side (Fig. 1). The center section was mounted behind a jeep, and the wings were detachable. The boom mounting was equipped with a hydraulic lift, which raised the ends of the wings about 4 feet higher than the center section. This lifting of the boom permitted ready manipulation of the machine at the ends of the field. Provision was also made for raising the wings to a vertical position so that the machine could be driven through gates. When the machine was transported between widely separated fields, or on the road, the wings were removed and carried on a trailer along with extra aerosol tanks. Over all the boom was 24 feet long, 3 feet wide, and 6 inches deep. The boom was equipped with two sets of nozzles, one set composed of 24 oil-burner nozzles

[1] Results of a cooperative project between the University of Maryland and the Bureau of Entomology and Plant Quarantine on the value of liquefied-gas aerosols for the control of vegetable crop insects. This constitutes Scientific Paper 114, Contribution No. 1994 of the Maryland Agricultural Experiment Station.

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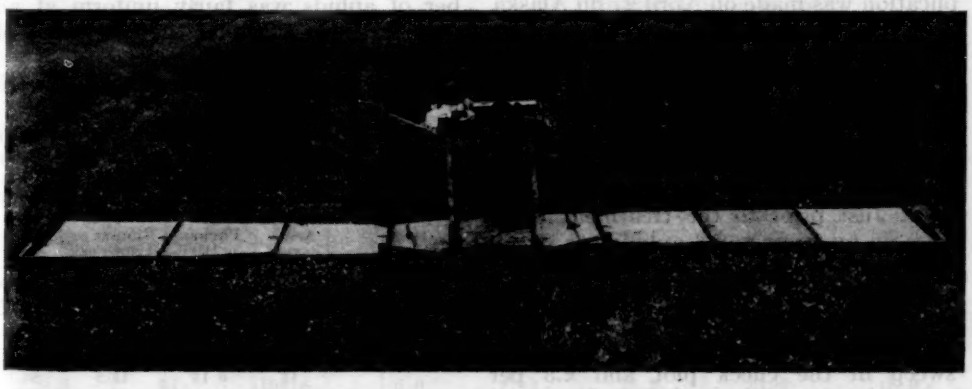

Fig. 1.—Aerosol dispenser mounted behind a jeep.

Table 1.—Aerosol formulas used in experiments on the pea aphid during 1945 (figures in per cent by weight).

Formula	Toxicant	Acetone	Aromatic Petroleum Solvent No. 202	Heavy Aromatic Petroleum Solvent	Cyclohexanone	Isophorone	Lubricating Oil	Methylated Naphthalene No. 1[1]	Methylated Naphthalene No. 2[2]	Valerolactone	Methyl Chloride
	DDT										
10	5	35	—	—	5	—	5	—	—	—	50
50	5	35	5	—	5	—	—	—	—	—	50
52	5	35	—	—	—	10	—	—	—	—	50
53	5	35	—	—	—	—	—	—	—	10	50
54	5	35	—	—	—	—	—	10	—	—	50
56	5	30	—	—	5	—	5	—	—	—	55[3]
57	5	30	10	—	5	—	—	—	—	—	50
58	5	25	5	—	5	—	—	—	—	—	60
	Rotenone										
59	2	35	5	—	5	—	—	—	—	—	53
	DDT										
60	5	35	10	—	—	—	—	—	—	—	50
61	5	35	—	10	—	—	—	—	—	—	50
62	5	35	—	—	—	—	—	—	10	—	50
63	5	30	5	—	5	—	—	—	—	—	55[3]
65	5	35	—	—	5	—	—	5	—	—	50

[1] A mixture of di- and tri-methylated naphthalene (*Velsicol AR 60*).
[2] A methylated naphthalene designated as *PD 544-B*.
[3] Contained traces of hydrochloric acid.

rated to discharge 2 gallons per hour in pairs 2 feet apart, and the other 16 nozzles of 3-gallon-per-hour capacity in pairs 3 feet apart. The nozzles were arranged to direct the aerosol downward at an angle of 45° and a like angle to the left or right, as described by Ditman *et al.* (1945). The 2-gallon-per-hour nozzles were used in all experiments except where noted.

The aerosol solutions were handled in ordinary methyl chloride cylinders which held 80 pounds of solution.

EXPERIMENTAL WORK.—The first application was made on April 27 on Alaska peas near Easton, primarily for the purpose of testing the dispensing equipment. At the time of application there was a drizzling rain with a wind velocity near 20 miles per hour and a temperature of 55°F. The aerosol in formula 50 (Table 1) was applied at a jeep speed of 5 miles per hour. Just prior to the treatment there were on an average 2.3 aphids per sweep on the aerosol-treated plot and 13.1 aphids per sweep on an adjacent untreated plot. On May 9, or 12 days later, the number of aphids averaged 48.5 per sweep in the check plot and 2.3 per sweep in the treated plot, indicating a reduction of 94.4 per cent.

On May 9 treatments were applied to Alaska peas in an advanced stage of growth on which the aphid population had reached its peak and was rapidly declining. The plots varied in size from slightly over 1 acre to several acres.

In this field the same kind of aerosol was applied at different jeep speeds. At the 10- and 15-mile speeds the tip growths of the pea plants were snapped off by the projecting edges of the dispenser frame. On rough ground the wings tended to bounce. The reduction in number of aphids was fairly uniform at all speeds (Table 2) under the conditions of this experiment.

Seven treatments were applied on April

Table 2.—Results of treatments with aerosols applied at different speeds on Alaska peas. Easton, Md.

Active Ingredient	Formula	Speed of Application, Miles per Hour	Pounds of DDT Applied per Acre	Number of Aphids per Sweep after Treatment (May 11)[1]	Reduction Per Cent of Check
Checks	—	—	—	96.4	—
DDT 5 per cent	50	5	0.5	11.1	88.5
		10	0.25	12.5	87.0
		15	0.15	15.3	84.1

[1] Average number of aphids per sweep for the entire field before treatment 282.9.

Table 3.—Comparison of three aerosols applied at different jeep speeds on Alaska peas, Ridgely, Md.

Formula	Speed, Miles, per Hour	Pounds DDT per Acre	Aphids per Sweep after Treatment (May 8)[1]	Reduction, Per Cent of Check	Shelled Peas, Pounds per Acre	Increase, Per Cent of Check
			Untreated checks			
—	—	—	417.3	—	1535	—
			DDT 5 per cent			
10	6	0.4	9.7	97.7	2570	67.4
	5	0.5	11.1	97.3	1699[2]	10.7
	3	0.8	5.0	98.8	2222	41.1
57	3	0.8	4.0	99.0	2418	57.5
58	3	0.8	1.7	99.6	2309	50.4
	5	0.5	3.5	99.2	2200	43.3
	7	0.36	12.7	96.9	2156	40.5

[1] Average number of aphids per sweep from the part of the field included in experimental plots 162.6 per sweep before treatment.
[2] Not all the peas were cut off and harvested in this plot, because of poor performance of mower over uneven ground.

28 to Alaska peas on a farm near Ridgely, at temperatures ranging between 53° and 59° F., and with a wind velocity near 12 miles per hour. At this time the peas were about 12 inches high, and samples in various portions of the field averaged 162.6 aphids per sweep. The tests included a comparison of three aerosol formulas applied at 3 miles per hour and also at higher speeds for two of them (Table 3). The reduction of aphids 10 days after treatment shows that the higher speeds were less effective with both formulas 10 and 58, although the differences were small and were not uniformly reflected in yields. The checks and the untreated portion of the field were browned by aphid feeding and had to be harvested 1 week before the treated areas. Not only were the yields greater but the quality of peas was higher in the plots treated with aerosol.

In another experiment conducted at Ridgely each of 10 aerosols was applied to 3 replicated plots of Alaska peas on May 9 at the rate of 5 miles per hour. Each plot was about 0.033 acre in extent. The vines were beginning to blossom. The day was clear with a temperature of 59°–65°F., and a wind of 11.4 miles per hour velocity was blowing across the plots. The object was to compare aerosols containing DDT in various solvents and one containing pure rotenone dissolved in acetone.

Sweeps made 2 days after treatment (Table 4) showed that the number of aphids in the check plots was also reduced, apparently by the drift of the finer particles of aerosol from adjacent plots.

Table 4.—Comparison of various aerosol formulas on Alaska peas, Ridgely, Md.

Pounds per Acre	Formula No.	Aphids per Sweep			Reduction Per Cent of Check (May 19)	Shelled Peas, Pounds per Acre	Increase Per Cent of Check
		May 8	May 11	May 19			
			Checks				
—	—	83.1	17.6	124.7	—	2616	—
			DDT 5 per cent				
0.5	52	73.2	4.4	15.0	87.9	2823	7.9
0.5	53	107.2	11.8	22.2	82.2	3046	16.4
0.5	54	89.6	6.2	17.3	86.1	3310	26.5
0.5	56	84.2	6.0	19.2	84.6	3397	29.9
0.5	57	106.2	6.3	16.3	86.9	3254	24.4
0.5	58	92.6	6.2	15.5	87.6	2704	3.4
			Rotenone 2 per cent				
0.2	59	46.3	11.6	68.1	45.4	—	—
			DDT 5 per cent				
0.5	60	105.7	7.3	18.5	85.2	2895	10.7
0.5	61	102.6	6.0	17.1	86.3	3102	18.9
0.5	62	90.3	7.1	16.3	86.9	3669	40.3

However, 10 days after treatment the aphids had increased greatly in the check plots, indicating that the drifting aerosol did not have a residual toxic action. The aphids increased very little in the plots treated with DDT, and moderately in the plots treated with rotenone. A comparison at this time indicated a reduction of 82 to 88 per cent by the DDT aerosols and only 45 per cent by the rotenone aerosol. The yield of peas at harvest was greater in all DDT-treated plots than in the checks, but considerable differences occurred between treatments, which were not correlated with aphid control. These differences were also not correlated with any visible foliage injury that developed following treatment. No injury followed the treatments with aerosols containing the solvents isophorone, gamma-valerolactone, methylated naphthalene No. 1, lubricating oil, and heavy aromatic solvent (Formulas 52 to 56 and 61); yet considerable differences in yields occurred.

In a comparison of formulas 57, 58, and 60 containing the same aromatic petroleum solvent, a 10 per cent concentration caused objectionable injury while a 5 per cent concentration (Formula 58) caused only slight injury; yet the yields were lower with the latter. The rotenone aerosol (Formula 59) caused more noticeable foliage injury than did the DDT aerosol (Formula 58) containing the same proportion of the solvent. Further, the methylated naphthalene No. 2 (Formula 62) caused conspicuous browning and spotting of leaves on many plants and yet the yields were higher than in any other treatment. It may therefore be concluded that, although injuries to the foliage by certain solvents were obvious, the peas outgrew any deleterious effect. Because of the evident temporary reduction of aphids by the drifting aerosol in the check plots immediately after treatment, larger plots would have permitted sampling of checks beyond drift of the aerosol.

Another experiment was conducted in a 25-acre field of Alaska peas at Gaithersburg, in which aerosols were applied to one series of plots on May 16, earlier than was considered best, and to another series on May 22, when growth of plants and aphid populations had reached the stage where treatment was desirable. One aerosol (Formula 50) was applied at various speeds on May 16 at a temperature of 82° F. and a wind velocity of 12 miles per hour; and on May 22, at a temperature of 84° F. and wind velocity of 18 miles per hour, two formulas were compared when applied at the same speed.

As indicated in table 5, the reduction of aphids by treatments on May 16 at speeds of 3 or 5 miles per hour was greater than by treatments at 10 or 15 miles per hour. The treatments on May 22 with two aerosols at the same speed

Table 5.—Experiment with aerosols applied on different dates on Alaska peas, Gaithersburg, Md.

Date Treated	Formula	Speed, Miles per Hour	Pounds of DDT per Acre	Aphids per Sweep			Reduction, Per Cent (May 31)	Shelled Peas, Pounds per Acre	Increase Per Cent of Check
				(May 16)	May 21	May 31			
				Check					
—	—	—	—	72	151.5	746.7	—	1733	—
				DDT 5 per cent					
May 16	50	15	0.15	49.3	24.1	136.1	81.8	2344	35.3
		10	0.25	36.1	10.8	30.7	95.9	—	—
		5	0.5	87.7	3.8	12.9	98.3	—	—
		3	0.8	68.3	3.0	13.9	98.1	—	—
May 22	65	5	0.5	57.1	146.1	7.8	98.9	2640	52.4
			0.5	56.9	117.3	13.5	98.2	—	—
	63	5	0.5	246.4	83.2	12.1	98.4	—	—
			0.5	58.7	111.1	8.3	98.9	—	—
			0.5	36.0	67.2	14.3	98.1	—	—

indicated a uniformly high degree of efficiency in all replicates. The reduction of aphids by treatments at both dates was similar and indicated that there is considerable latitude in the time during which the peas may be treated. Although it was not possible to take yields for all plots, the increases in yield per acre obtained from two plots were 611 and 907 pounds. As in the experiment at Ridgely (Table 3), the treated peas remained green and in succulent growth a week longer than the checks.

On the afternoon of May 31, at a temperature of 73° F. and a wind velocity near 13 mph., three aerosols were applied at the rate of 5 miles per hour to wrinkled peas to compare the efficiency of different-sized dispenser nozzles. Each aerosol was applied to duplicated 1-acre plots at the rate of 5 miles per hour to give a dosage of 0.5 pound of DDT per acre with 24 2-gallon-per-hour nozzles or 16 3-gallon-per-hour nozzles. No consistent differences were observed between any of the treatments (Table 6). These results indicated that larger nozzles can be used satisfactorily. It was of interest that throughout the field, least bronzing of foliage occurred where formula 65 was used, formula 54 was intermediate, and formula 50 caused greatest injury.

Table 6.—Experiment with three aerosols applied with different nozzles on wrinkled peas, Gaithersburg, Md.

Formula	Nozzle Output, Gallons per Hour	No. of Aphids per Sweep[1] before Treatment (May 31)	No. of Aphids per Sweep[1] after Treatment (June 4)	Reduction, Per Cent of Check (June 4)
Untreated checks				
—	—	161.6	113.0	—
DDT 5 per cent				
50	2	98.9	24.2	78.6
	3	82.2	25.0	77.9
54	2	93.4	32.9	70.9
	3	92.6	28.3	74.9
65	2	150.9	19.5	81.9
	3	111.5	25.2	77.8

[1] Average from 2 replicated plots.

One experiment of 29 acres was nullified by frequent stoppage of nozzles due to corrosion as a result of impurities in the methyl chloride used in formulas 56 and 63.

DISCUSSION.—In 2 years' experiment with DDT against the pea aphid, best results have always been secured against flourishing aphid infestations. For example, the results in tables 3 and 5 were obtained under conditions of a highly vigorous infestation. In tables 2 and 6, where aphid infestations were of low vigor, the percentage reduction of aphids is much lower. This is to be expected, since a rapid increase in check plots always causes a greater difference in aphid population between treated and nontreated plots provided the treatment was satisfactory. On the other hand, there is evidence that DDT aerosols are not as effective against populations of aphid of low vigor, i.e., the actual percentage of kill is lower (Table 6). More observations are needed before definite conclusions can be drawn on this point.

The most serious mechanical problem which developed in the work with aerosols was that of nozzle stoppage. The causes were (1) fine particles of dirt in the aerosol solutions, (2) crystallization of insecticide in the nozzles, and (3) formation of insoluble precipitates from corrosion of the containers or feed lines by acids in the aerosol solutions. The first was corrected by the use of a butane carburetor filter. When DDT was used the second cause was corrected by replacing the lubricating oil in the aerosol solution with a nonvolatile aromatic petroleum oil such as *Velsicol AR-60* which has a higher solvent power. Corrosion of containers and feed lines can be greatly reduced by adding 1 per cent of propylene oxide to the aerosol solution. When good grades of materials are used, this amount is sufficient to combine with any acids present or with those produced when the solutions are allowed to stand. It is advisable to use only refined methyl chloride until further experimental work has been done. Even refined methyl chloride will require propylene oxide as a stabilizer. The use of nozzles larger than the 2-gallon-per-hour size may reduce the chances of clogging.

The aerosols were effective under varying conditions, including temperature extremes of 54° to 84° F., varying wind velocities, and both in sunshine and in rain. The occurrence of rather sharp lines of demarcation between treated and aphid-injured untreated plots indicated that there was little drift of the aerosol.

Applications of aerosols containing 0.5 pound or more of DDT per acre at jeep speeds of 3 to 5 miles per hour gave consistently better results than did smaller quantities applied at higher speeds.

The treatments on Alaska peas have generally given greater percentage reduction of aphids than those on the heavier growth of the wrinkled varieties. In addition to variations in the vigor of the infestations, the aphids on the wrinkled peas may be better protected by the larger leaves. This may require modification in the method of application.

The slower maturation of treated peas tends to increase yields and allow more leeway in harvesting as an aid in securing higher quality.

Because of the changing prices of the ingredients of the various aerosols tested, no cost figures are included. At the present time, however, formula 54 with methylated naphthalene as the solvent is probably the cheapest but formula 65 with both cyclohexanone and methylated naphthalene has been tested most extensively.

SUMMARY.—Aerosols containing 5 per cent of DDT in various formulas were applied to about 100 acres of Alaska and varieties of wrinkled peas with a dispenser designed for commercial use that was mounted on a jeep. Treatments with dosages of 0.5 pound of DDT per acre at speeds of 3 to 5 miles per hour were more uniformly effective than higher speeds and lower dosages. Nozzles having an output of 3 gallons per hour were comparable to the previously used 2-gallon-per-hour nozzles. Successful treatments were made during varying weather conditions, including temperatures between 54° and 84° F., wind velocities up to 20 miles per hour, and in sunshine as well as rain. Treatments resulted in 97 to 99 per cent reduction of the aphids and in yield increases of 10 to 67 per cent where the infestations were heavy. Better control of aphids and greater increase in yield of peas were obtained on Alaska peas than on wrinkled varieties, but this may have been due in part to differences in vigor of the infestations. Nozzle stoppage due to corrosion particles or formation of crystals was largely corrected by including a methylated naphthalene in the solution, adding 1 per cent of propylene oxide to combine with any free acids, and installing a filter in the line.—2-8-46.

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"PER CENT DDT"

Confusion exists in the usage in discussion of strengths of DDT mixtures used in experiments and in recommendations issued for the guidance of the public.

Some formulations call for DDT at a stated per cent strength; others deal in pounds per gallon of liquid. And in some cases there have been very definite mistakes implied in the formulas. In any case, it is confusing to the public and to other investigators, to have the variation in the usage.

Inasmuch as it is the general custom to state dilutions of solid materials, and even of some liquid insecticides, in terms of pounds per gallon, or pints, quarts or milliliters per given volume of diluent, would it not be desirable for us all, by common consent, to adopt this method of stating the proportions of DDT to be used in the various mixtures, liquid or dry, which are to be applied for treating various insects.

Mixtures of the dry water-miscible preparations may well be given in such form as to indicate the mass of actual DDT per given volume of water. And it will be convenient, and probably will be generally satisfactory, to indicate dilution of liquid preparations of DDT in terms of volume per volume or, in some cases, actual weight of DDT for a given volume of spray mixture.

This suggestion is made in the hope that greater uniformity of use in *Journal* publications may result from its adoption, should it find favor with the writers of reports in this field of investigation.

DDT to Control Potato Aphids

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DDT as an insecticide for potato insect control is superior to other materials used heretofore. It appears to be destined to become favored over such standard insecticides as nicotine, rotenone, pyrethrum and the various synthetics of recent introduction.

There seems to be little discord in the findings of research workers that DDT is very effective in suppressing infestations of flea beetles, *Epitrix cucumeris*, leafhoppers, *Empoasca fabae*, and various Mirids all of which are important pests of potatoes in New York. Information on its effectiveness as an aphicide is somewhat conflicting and confusing. Control is satisfactory for some species but in other cases DDT has been found to have little practical value.

Previous work reported by Gyrisko *et al.* (1945) indicated control of potato aphids was better with DDT than with either rotenone or nicotine. In Nebraska, Hill (1945) found that aphid populations were considerably lower on potato plants treated with DDT than on comparable untreated plants. The infestations were extremely low in comparison with those which bring concern to New York potato growers. A method of field application by gas aerosol dispersion was found by Smith and co-workers (1945) to be very promising as a means of aphid control in heavily infested potato plantings. In their experiments DDT was fully as effective as nicotine.

The experimental work reported in this paper adds to the existing knowledge of the efficacy of DDT as a control for the two principal species of potato aphids, *Macrosiphum solanifolii* and *Myzus persicae*. Heavy infestations of the former occur annually on Long Island lasting for a period of two to three weeks. Appearing at a time when the tuber crop is making rapid growth these aphids usually cause appreciable reductions in yields. Cognizant of this fact, growers resort to the use of nicotine, rotenone and the thiocyanates when necessity dictates.

Outbreaks of aphids in the upstate potato growing regions are sporadic and unpredictable; the locale varies from one year to another. During the past season an extremely heavy infestation of *Myzus persicae* developed in western New York, centered in Monroe County. Fortunately potato spraying experiments had been assigned to this area so that there was an excellent opportunity available to determine the effectiveness of DDT in suppressing *M. persicae*.

Materials and Methods.—Most of the insecticides used were proprietary formulations. The DDT spray powder designated as *AK-40*[1] was said to contain 40 per cent technical DDT and a wetting agent. A small quantity of *B-1956*[2] was added to facilitate spreading. Dusts were made from a concentrate containing 40 per cent technical DDT with pyrophyllite as a diluent. The content of DDT in the emulsifiable solutions varied considerably as did the solvents and emulsifiers. An alcoholic solution was made by dissolving the desired quantity of DDT in tetrahydrofurfuryl alcohol to which was added a specific amount of *Triton X-100*.[2] Upon dilution of this solution with water, the DDT was precipitated in a finely divided suspension. Sufficient *Triton X-100* to retard conglomeration of the DDT particles was necessary and amounted to approximately 10 per cent by volume of the concentrated solution.

Applications were made on commercial acreages with power equipment and in schedules consistent with those recommended to growers. Plots, randomized in most cases, were replicated four or more times. Aphid population estimates were taken either by net sweeping or by leaf count.

All plots were treated for disease control with a fungicide, standard bordeaux mixture or neutral copper, and the insecticides were included when scheduled in the spray or dust program.

Results and Discussion.—The results from several experiments on Long Island, table 1, agreed consistently that DDT reduced aphid populations more than other aphicides with the exception of nicotine fumigation. As is usual with nicotine sulfate at the recommended

[1] Geigy Co.
[2] Rohm and Haas Co.

strength, 1 to 400, the control averages slightly more than 50 per cent. *Lethane B-71* and *72* are about equal to nicotine in effectiveness but the 3-way rotenone-pyrethrum dust is not as dependable. DDT in both sprays and dusts at the concentrations used gave reductions of approximately 80 per cent and approached that obtained by nicotine fumigation.

Table 1.—Effectiveness of DDT in comparison with other insecticides for control of the potato aphid, *Macrosiphum solanifolii*.

Insecticide	Concentration per 100 Units of Spray or Dust	Per Cent Reduction of Population by	
		First application	Second application
Experiment 1			
DDT spray powder	2 lbs. DDT	77.3	81.9
DDT dust	3% DDT	76.7	78.0
Nicotine sulfate	1 quart	53.9	64.3
3-way dust	.75% rotenone .075% pyrethrins	36.2	29.2
Experiment 2			
DDT spray powder	2 lbs. DDT	82.4	82.1
Nicotine sulfate	1 quart	76.6	58.1
Lethane B-72[1]	3.5 lbs. powder	54.3	71.9
Nicotine fumigation		—	96.5
Experiment 3			
DDT dust	2% DDT	78.5	
Nicotine dust	4% Nicotine	68.2	
Lethane B-71	2% Lethane	49.5	
3-way dust	.75% rotenone .075% pyrethrins	40.5	
Experiment 4			
DDT spray powder	2 lbs. DDT	87.7	83.8
Nicotine sulfate	1 quart	64.9	56.2
Experiment 5			
DDT spray powder	2 lbs. DDT	84.7	89.0
Nicotine sulfate	1 quart	55.0	51.2
Experiment 6			
DDT dust	3% DDT	87.0	
3-way dust	.75% rotenone .075% pyrethrins	30.8	
Experiment 7			
DDT spray powder	2 lbs. DDT	83.5	82.9
Nicotine impregnated powder[2] DDT	3 lbs. 1 lb. DDT	73.7	78.5
Nicotine impregnated powder	6 lbs.	52.4	63.9

[1] Beta beta dithiocyano diethyl ether; Rohm and Haas Co.
[2] *Black Leaf Concentrate* 17 per cent nicotine; Tobacco By-Products Co.

Comparisons similar to those previously mentioned were not made in Monroe County where *Myzus persicae* presented a problem. However, it is evident from data taken after two or three applications of DDT that control of this species was exceptionally good and better than in the case of *Macrosiphum solanifolii* on Long Island.

The ability of a DDT deposit to check reinfestation and build-up of populations of many insects has been one of the important attributes of this new material. However, in the work of 1944, Gyrisko *et al.* reported that the residual effectiveness of DDT was not outstanding in their preliminary work with aphids on Long Island. Observations from a number of the past season's experiments, table 2, confirm that *Macrosiphum solanifolii* will increase rapidly in numbers a few days following an application of DDT. The rate of recovery of the populations is greater with DDT than with other aphicides or the controls. These observations indicate the need for applications at frequent intervals to insure proper protection from aphid damage.

Table 2.—Reduction of *Macrosiphum solanifolii* after insecticide applications and subsequent increases in populations.

Insecticide	Aphids in 80 Net Sweeps			Rate of Increase
	Before application	48 hours later	Before next application	
Experiment 1			6 days later	
.75% DDT dust	5697	2332	3891	1.67
1.0% DDT dust	6118	1738	3421	1.97
3.0% DDT dust	7144	1131	2575	2.28
5.0% DDT dust	6506	5656	8441	1.49
Experiment 2			8 days later	
2 lbs. DDT spray	1536	422	1197	2.84
3% DDT dust	1396	393	1042	2.65
4% Nicotine dust	1399	780	1343	1.72
3 way dust	1658	1281	1369	1.07
No aphicide	1827	2261	3423	1.54
Experiment 3			6 days later	
2 lbs. DDT spray	4242	584	4424	7.58
Emulsion QTH[1]	4285	648	5032	7.77
Alcohol THF[2]	4454	642	4456	6.94
Nicotine sulfate	4109	1590	5351	3.37
No aphicide	5201	5688	6120	1.08
Experiment 4			7 days later	
2 lbs. DDT	1495	435	696	1.60
None	1506	2659	3387	1.27
Experiment 5			8 days later	
2 lbs. DDT	1125	138	1604	11.62
Nicotine sulfate 1–400	1393	714	4906	6.87
No aphicide	1493	1703	4882	2.87

[1] From U. S. Rubber Co. contains 14 per cent DDT.
[2] Contains tetrahydrofurfuryl alcohol from Quaker Oats Co.

The situation with *Myzuse persicae* in Monroe County differed from that of *Macrosiphum solanifolii* in that populations of the former remained at very low levels even after 8 to 18 days following application of DDT. This is pointed out in the data summarized in table 3. In contrast to the pronounced increase in populations of *M. solanifolii* between application intervals it would appear that residual action is more effective in the case of *M. persicae.*

Habits of the two species may be the reason for the difference. Laboratory experiments have shown that a DDT de-

Table 3.—Aphid populations, *Myzus persicae*, several days following spray applications of DDT.

	Material per 100 Gallons	Aphid Population per Leaf	
		number	Per cent reduction
Experiment 1			
16 to 18 days after second application	1 lb. DDT	8.0	94.7
	none	168.9	
9 days after third application	1 lb. DDT	29.4	83.3
	none	176.3	
Experiment 2			
8 days after third application	1 qt. 20% DDT	5.9	97.0
	none	190.6	
Experiment 3			
8 days after third application	1 qt. 20% DDT	5.4	95.7
	none	124.8	
11 days after fourth application	1 qt. 20% DDT	2.6	96.0
	none	64.9	

posit on potato foliage is highly toxic to both species. *Macrosiphum solanifolii* infests the terminal growth and flower stalks until overcrowding or death of the terminals forces the populations to descend to the lower leaves. With foliage growth being rapid during the infestation period a large proportion of the aphid population would not come in contact with DDT deposits on the fully expanded leaves. Populations were reduced sharply after application but the small percentage not killed is enabled to increase rapidly on the new terminal growth. *Myzus persicae* on the other hand inhabits the lower levels of the plant where the presence of DDT deposits may inhibit rapid build-up of the aphid population.

The concentration of DDT needed to give satisfactory control of potato aphids is somewhat higher than that suggested for use when leafhoppers and flea beetles are a problem. Data are presented in table 4 from a number of experiments comprising a series of concentrations of dust, spray powder and emulsifiable solution. In formulating plans for these experiments the highest levels of DDT used were thought to be more than necessary for adequate aphid control. However, control increased with each increment in dosage although the differences between one and two pounds of DDT in spray powder form or between 3 and 5 per cent dusts seem too small to have an appreciable effect on yields. This was not the case as significant increases in yields were recorded in favor of the higher concentrations. These results suggest a 2-pound dosage of DDT to 100 gallons of spray in powder form or a 5 per cent dust in the control program during the aphid infestation period. Since New York growers apply 100 to 125 gallons of spray or 35 to 50 pounds of dust per acre these dosages may be translated to approximately 2 pounds of DDT on an acre basis.

Table 4.—Concentration of DDT and effectiveness in control of potato aphids.

Concentration of DDT	Per Cent Reduction of Populations	
	First count	Second count
Experiment 1—*Macrosiphum solanifolii*		
0.5 lb. DDT/100 g	64.6	72.4
1.0 lb. DDT/100 g	71.8	80.6
2.0 lb. DDT/100 g	75.6	83.6
Experiment 2—*Macrosiphum solanifolii*		
0.75% DDT dust	60.6	48.5
1.0 % DDT dust	72.6	70.9
3.0 % DDT dust	84.8	79.8
5.0 % DDT dust	85.9	85.4
Experiment 3—*Myzus persicae*		
0.25 lb. DDT/100 g	45.2	50.4
0.50 lb. DDT/100 g	88.0	83.6
1.0 lb. DDT/100 g	95.3	83.3
Experiment 4—*Myzus persicae*		
0.5 lb. DDT/100 g	75.1	
1.0 lb. DDT/100 g	97.7	
2.0 lb. DDT/100 g	99.8	
Experiment 5—*Myzus persicae*		
.5 pt. solution[1]/100 g	19.5	
1 pt. solution/100 g	69.6	
2 pts. solution/100 g.	97.9	

[1] 20% DDT solution (*Gesarol*).

SUMMARY.—Two species of aphids, the pink and green, *Macrosiphum solanifolii* and the green peach, *Myzus persicae*, are important potato pests in New York's potato producing areas. Field experiments conducted during the past season on Long Island and in western New York showed that DDT was a better aphicide than such standard materials as rotenone, nicotine and the thiocyanates.

DDT reduced populations more than the other insecticides in experimental field comparisons except nicotine fumigation. The residual effectiveness for which DDT is noted was not as pronounced in the case of *Macrosiphum solanifolii* as it was with *Myzus persicae*. Populations of the former recovered or built up faster between applications than did the latter. This may be due to a difference in the

region of the plant infested by the two species. *Macrosiphum solanifolii* is found chiefly on the rapidly growing terminals whereas *Myzus persicae* inhabits the lower level of the plant and is more likely to be in contact with DDT deposits than in case of the former species.

In comparisons of several concentrations of dust, spray powder and emulsifiable solution control of aphids and tuber yields increased with each increment of DDT used. The results suggest that at least 2 pounds of DDT per acre as spray powder or dust are needed in each application during the aphid infestation period. Applications at frequent intervals are necessary to keep populations at a reasonably low level. This was more important in case of *Macrosiphum solanifolii* than *Myzus persicae*.—12-20-45.

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DDT for Codling Moth Control in Western New York in 1945[1]

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This paper presents the results of orchard tests in codling moth control with DDT sprays during the past season. A report on similar work during 1944 has been published (Harman 1944).

The almost complete apple crop failure this past year in western New York made it difficult to find orchards in which to carry on the work. However, a few plantings were located in codling moth-infested territory where a limited number of field tests were made.

FIELD TESTS.—A 20-year-old apple orchard located one half mile from the shore of Lake Ontario in Monroe County provided interesting data on a number of comparative tests. This orchard was planted to the varieties Wealthy, McIntosh and Baldwin.

A *Friend* orchard sprayer equipped with a 20 gallon a minute pump carrying 450 pounds pressure was used for the work. All applications were made with a 6 nozzle boom gun operated from a platform on the sprayer. Approximately 1 gallon of spray per bushel of fruit was applied at each application.

The tests were made on single tree plats scattered at random throughout the orchard and each treatment was applied to at least one tree each of Wealthy, McIntosh and Baldwin varieties. Four cover sprays were applied, three for the first brood worms on June 26, July 9 and 16, and one for the second brood on August 13.

The following materials were used.

Gesarol AK 40 containing 40 per cent DDT, a product of Geigy Company, Inc.

DDT Concentrate containing 17 per cent DDT and *Black Leaf Dry Concentrate—DDT blend* containing 7 per cent nicotine and 17 per cent DDT. These were prepared by the Tobacco By-Products and Chemical Corporation, Inc.

Deenate 25W containing 25 per cent DDT, a duPont product.

Corona lead arsenate manufactured by the Pittsburgh Plate Glass Company.

Triton B-1956 an emulsifier and spreader produced by Rohm and Haas Company.

The average control of the codling moth by each treatment is given in table 1.

Wettable sulfur was employed in all sprays as a fungicide with the exception of plat 3 in which 0.75–2–100 bordeaux was substituted in place of sulfur in the last two cover sprays. The spreader, *Triton B-1956* was used on plats 1, 2, 3 and 8.

The data in the above table represent the average control for all trees in each plat. The infestation was about average for the section and not difficult to handle. The check tree data offered a good illus-

[1] Journal Paper No. 000, New York State Agricultural Experiment Station, Geneva, New York.

Table 1.—Codling moth control in 1945.

Plat No.	Spray Materials per 100 Gallons	Number of Trees	Stings on 100 Apples	Worm Holes in 100 Apples
1	*AK-40*, 2.5 lbs.	5	2.6	0.7
2	*AK-40*, 3.75 lbs.	4	2.4	0.5
3	*AK-40*, 1.25 lbs.+Lead arsenate 2 lbs.	4	2.6	0.5
4	DDT Concentrate 3 lbs.	3	2.7	1.0
5	DDT Concentrate 6 lbs.	3	2.0	0.4
6	*Black Leaf* dry concentrate-DDT blend 3 lbs.	3	2.7	0.8
7	*Deenate 25W*, 4 lbs.	5	3.8	0.9
8	Lead arsenate 3 lbs.+hydrated lime 2 lbs.	3	25.8	2.4
9	Checks, no cover sprays	5	42.4	85.5

tration of the comparative attractiveness of the three varieties for the codling moth. The Wealthys were 72.4 per cent wormy, the Baldwin 85.5 per cent and the McIntosh counts showed 111 worm holes in 100 apples. DDT used at the rate of one pound of actual DDT in 100 gallons of water gave practically identical control with each product and there was an indication of better control of worms than was secured with lead arsenate. However, as this infestation was not difficult to combat with lead arsenate, the differences in control were not great. There was a noticeable difference in the number of stings in favor of the DDT.

Plat 3 is interesting for the reason that lead arsenate may be desirable in the summer apple spray program for curculio and apple maggot.

Spray Residue.—One of the problems of the western New York fruit grower has been that of spray residue. Fruit protected by a lead arsenate spray program consisting of four or more cover sprays usually retains excessive amounts of residue at harvest. The residue analyses of fruit from the above tests are given in table 2.

The spray program consisted of four cover sprays applied between June 26 and August 13. The visible residue was comparatively light on plats 1, 2, 3, 4, 5 and 6. On plats 3, 7 and 8 it was more noticeable and brushing was desirable.

With the tentative tolerance of .05 grain DDT per pound of fruit the determinations of residue on the apples at harvest as given in table 2 indicate there should be little difficulty in keeping within the legal allowance following a DDT spray program on apples. In comparison the lead (tolerance .05 grain) and arsenic (tolerance .025 grain) deposits were more than double the permitted amount following the standard spray schedule (Plat 8).

Growers Tests with DDT.—There were a number of so called grower tests made with DDT under the supervision of the author. These tests were important for the reason that the average spray program applied by a fruit grower is usually less efficient as compared with the work of an investigator and it is not unusual for a grower to fail while a trained worker may be successful in attempting to combat a pest like the codling moth.

One orchard selected was a Niagara County planting representative of the most severe codling moth conditions in New York State. Three years experimental spraying in this orchard had previously shown that lead arsenate did not provide satisfactory control in that area.

During 1944, 10 cover sprays of double strength lead arsenate supplemented with nicotine and with the addition of summer oil in all except the first three cover sprays resulted in 30 per cent serious injury from worms and stings. Grower spraying netted 45 per cent culls at harvest. It actually cost more to raise these apples than they were worth during normal times.

With DDT, at the rate of one pound in 100 gallons, applied in five cover sprays during 1945, the fruit picked was 99 per cent free of codling moth injury on the varieties Delicious and McIntosh. Unsprayed trees were 100 per cent wormy by the first of August and 95 per cent of their crop was on the ground by the middle of that month. By actual count, not a single apple was found on the check trees with as few as one worm hole per apple, and

Table 2.—Spray residue, 1945[1]

Plat No.	Spray Materials per 100 Gallons	Grains per Pound of Fruit		
		DDT	Arsenic	Lead
1	*AK-40*—2.5 lbs.	.015		
2	*AK-40*—3.75 lbs.	.024		
3	*AK-40*—1.5 lbs.+Lead arsenate 2 lbs.	.008	.030	.068
4	DDT Concentrate 3 lbs.	.021		
5	DDT Concentrate 6 lbs.	.026		
6	*Black Leaf* dry concentrate-DDT blend 3 lbs.	.003		
7	*Deenate 25W*, 4 lbs.	.015		
8	Lead arsenate 3 lbs. + hydrated lime 2 lbs.		.053	.118

[1] DDT analyses were made by R. H. Washburn of Cornell University using the Gunther method.
Lead and Arsenic determinations were made by A. W. Avens, State Experiment Station, Geneva, N. Y.

as many as 38 active worm holes were counted on individual fruits in mid-summer.

This same fruit grower had a somewhat similar experience with pears, the DDT sprayed fruit being free of worms and visible spray residue. The lead arsenate sprayed fruit in the same orchard showed considerable worm damage and in addition was literally white washed with lead arsenate residue.

SPRAY INJURY.—With regard to spray injury, nothing of an injurious nature developed on either foliage or fruit as a result of the use of DDT sprays during 1945.

EUROPEAN RED MITE.—Contrary to the experience of investigators in other fruit growing areas, the European red mite, *Paratetranychus pilosus* C. & F., has not developed into problem proportions on DDT sprayed orchards in western New York during the past two seasons.

Apple trees sprayed with DDT were noticeably free from red mites during the spraying season while adjoining unsprayed trees showed 100 to 200 mites per leaf. Unsprayed Delicious trees were better than 50 per cent defoliated at harvest as a result of infestations of the red mite. The mites did not commence to build up on the DDT plats until after the spraying season which was so late in the summer that no noticeable damage to the crop developed other than some bronzing of foliage on Baldwins. On the other hand, the heaviest deposition of red mite eggs was found at harvest on Baldwin apples that had been sprayed with DDT to combat the codling moth.

It is possible that we may encounter trouble with the European red mite on apples in the near future and indications suggest that such a problem is very possible. However to date this pest has not developed to problem proportions as a result of the use of DDT sprays.

NEW FORMULA FOR USING DDT.—A new formula for preparing DDT sprays was developed this past season by Dr. Hugh Glasgow of this Station. It provides for the use of the pure chemical at considerable saving in cost. Preliminary tests on apples, although made late in the season after codling moth activity was past, indicated considerable promise.

Technical grade DDT is dissolved at the rate of one pound in one quart of benzene. This solution can be used as a tank mix emulsion with bordeaux or with *B-1956* or some other standard emulsifier. It is also possible that the DDT-benzene solution may be diluted directly with water requiring only agitation to make it usable as a spray, however, this method will require further testing under field conditions.

Tank mixed sprays prepared according to this formula and containing one pound of DDT in 100 gallons of water were used with perfect safety on potatoes, peas and apple foliage. Toxicity tests with cluster flies, *Pollenia rudis*, exposed to sprayed apple foliage indicated that the residue remained toxic for a noticeably longer period as compared with DDT applied in the standard suspension sprays. In tests with apples exposed to attack by several thousand oriental fruit moth larva, *Grapholitha molesta*, 3 per cent of the caterpillars entered the sprayed fruit as compared with 100 per cent entrances on unsprayed apples.

This formula appears to have several advantages over the suspended type of DDT sprays now available. The residue apparently remains toxic to insect life over a longer period; the kill seems to be quicker and more complete; there is no visible residue aside from that left by the emulsifying agent and the spray is easily prepared at approximately one-third the current cost of the dry concentrates.

SUMMARY.—For the second successive year DDT sprays have proved superior to lead arsenate for combating the codling moth in western New York orchards and they have been used with apparent safety to both fruit and foliage.

Analyses for spray residue on fruit treated with DDT indicate that it should not be difficult to keep within tolerance limitations even after using a full schedule of DDT in cover sprays.

It is possible that we may encounter trouble with the European red mite in the future, but to date this pest has not developed to problem proportions as a result of the use of DDT sprays.—1-14-46.

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DDT and *Ryanex* to Control Oriental Fruit Moth: Their Effect Upon Parasite Populations[1]

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In New York during most years several parasitic insects, principally the introduced braconid, *Macrocentrus ancylivorus* Rohwer have maintained a check on the populations of oriental fruit moth, *Grapholitha molesta* (Busck), adequate to provide commercial control of this pest in peaches. However, occasional failure in biological control in some orchards or sections of the peach growing areas within the state has created interest in the development of an effective chemical control method. The outstanding protection provided by DDT and the plant insecticide *Ryanex* against the oriental fruit moth on quince, as reported by the senior author (1945), has stimulated unusual interest in this question among growers. In preliminary tests on peaches in 1944, DDT did not entirely supress twig-infesting larvae. This fact and the known toxicity of DDT to *Macrocentrus* (Smith & Driggers, 1944) made it important to determine its effect upon populations of both fruit moth and parasites throughout the season when a complete schedule using this insecticide was applied to large blocks. Unprecedented injury to the fruit caused by second brood and especially third brood larvae of the fruit moth this past season provided an excellent opportunity to evaluate the performance of an insecticidal program to control this pest in peaches.

Method.—The mature Wayne County orchard selected for this investigation contains some 700 Elbertas and approximately 350 trees of the Rochester variety. All data were taken from the former. The orchard is partially cultivated and provides an abundance of protected spots highly suitable for fruit moth overwintering both on and beneath the trees or within the adjacent areas. These conditions and reported fruit infestation in this orchard in 1944 indicated a good population of fruit moth and the possibility of considerable natural parasitism. Blocks with 10 trees on a side were laid out as shown in figure 1.

[1] Journal Paper No. 651 New York State Agricultural Experiment Station, Geneva, N. Y., December 5, 1945.

The chemical treatments were made with a standard orchard sprayer using approximately 5 gallons of material per tree per application. More thorough coverage of the fruit was obtained in the latter two applications by placing one operator on a low platform while a second spray gun was handled from the tank. Sulphur dusts or sprays were applied throughout the orchard by the grower whenever necessary for brown rot control.

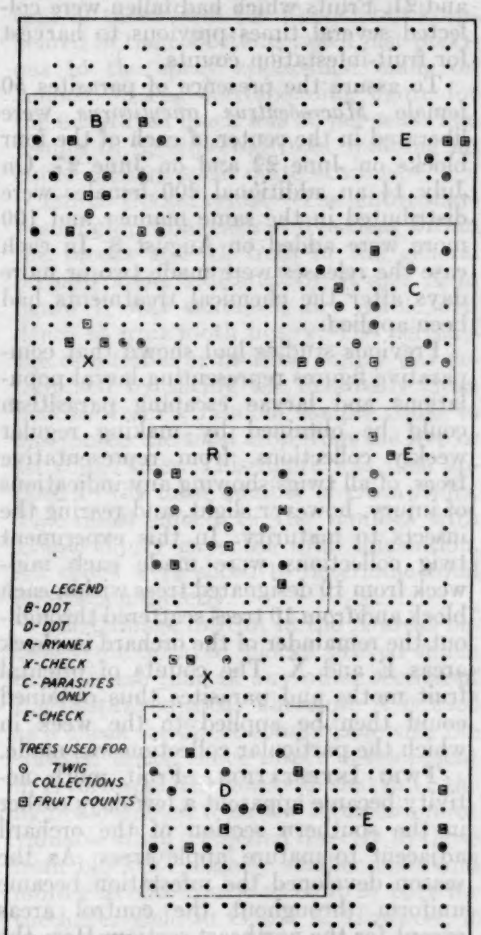

Fig. 1.—Diagram of orchard showing arrangement of blocks used to determine effect of insecticidal programs on oriental fruit moth and its parasites.

Ryanex[1] (R) was used at the rate of 6 pounds to 100 gallons with 1.6 ounces of B1956 added to improve the wetting and spreading qualities of the spray mixture. The DDT[2] was formulated as a 25 per cent water dispersible powder and used at concentrations giving one pound (D) and one-half pound (B) actual toxicant to 100 gallons. Both insecticides were applied four times during the season as follows: June 18, July 12, August 3 and 23. The fruit was harvested on Sept. 20 and 21. Fruits which had fallen were collected several times previous to harvest for fruit-infestation counts.

To assure the presence of parasites 50 female *Macrocentrus ancylivorus* were liberated in the center of each of the four blocks on June 22 and on June 27. On July 14 an additional 200 females were distributed in the same manner and 100 more were added on August 8. In each case the releases were made two or more days after the chemical treatments had been applied.

Previous studies had shown that comparative figures representing larval populations and larvae escaping parasitism could be obtained by making regular weekly collections, from representative trees, of all twigs showing any indications of injury, however slight, and rearing the insects to maturity. In this experiment twig collections were made each midweek from 10 designated trees within each block and from 10 trees scattered throughout the remainder of the orchard in check areas E and X. The counts of oriental fruit moths and parasites thus obtained could then be applied to the week in which the particular collection was made.

TWIG INFESTATION.—Fruit moth activity became apparent a few days earlier in the southern section of the orchard adjacent to mature apple trees. As the season developed the infestation became uniform throughout the control areas except for the northeast section. Here the injury remained relatively lighter. Hence the data obtained from B cannot be compared satisfactorily with those from D and are omitted from this discussion. The results obtained from collections taken outside the test blocks in areas E and X paralleled those from C rather closely except for a lower rate of parasitism. This rate may have been influenced by the failure to keep twigs taken from trees in the X areas separate from those collected in the E sections. It is not unlikely that the nearby sprays reduced the parasite populations in the two X areas as indicated later in this discussion. The data recorded from the weekly twig collections in blocks C, D and R are presented in figure 2.

It is quite evident that both chemical treatments materially reduced the number of oriental fruit moth larvae infesting the twigs. For example, a surprising increase in the number of worms in all blocks occurred during the week including August 1. Sprays were applied on August 3. The twig collections made during the following week from blocks R and D were greatly reduced in number and produced very few insects. This is in contrast to the condition in the unsprayed block C where the numbers of injured twigs and emerged insects remained high during the three succeeding collection periods. Similar tendencies can be noted throughout the season.

For a short period following each application the plant insecticide *Ryanex* seemed equal to DDT in effectiveness. However, a study of the data, particularly from the collections made subsequent to August 3, indicates poor residual action compared to DDT. These observations are substantiated by those made of the fruit infestation and are in agreement with the results secured in 1944 when *Ryanex* was used on quinces to control the fruit moth.

In New York state the season of 1945 proved most exceptional with respect to the lack of synchronization between the first brood oriental fruit moth and its principal parasites. Even where parasites were liberated, the excessive number of rain periods and the unusual scarcity of host larvae during June and early July gave the parasites little chance to reproduce in numbers. They proved quite inadequate to reduce effectively the surprisingly heavy, later generations. However, the presence of numerous parasites in the orchard under investigation is indicated clearly in the data for block C shown in figure 2 and table 1.

The almost complete absence of parasitic species other than *Macrocentrus* and the relatively low percentage of para-

[1] Furnished by Merck & Co., Inc.
[2] Furnished by E. I. du Pont de Nemours & Co.

sitized worms in the sprayed blocks must be attributed largely to the effect of the chemicals. It would appear also that the somewhat higher parasitism as well as the generally higher population recorded for the collections of August 1, three weeks after the preceding spraying, resulted in

Table 1.—Oriental fruit moth twig infestation and parasitism based upon collections from 10 trees in each treatment. All three blocks received parasites.

Brood and Treatment	Total Number per Tree		Parasitism Per Cent
	Twig-Infesting Worms	Parasitized Worms	
Brood 1			
No treatment	7.7	3.7	48.1
DDT	2.4	0.2	8.3
Ryanex	3.2	0.4	12.5
Brood 2			
No treatment	86.5	44.8	51.8
DDT	18.9	6.2	32.8
Ryanex	29.7	11.7	39.4

part from an infiltration of both moths and parasites from surrounding areas.

Judging by the results recorded here it seems probable that 2 or more applications of DDT made at 2- to 3-week intervals throughout a peach orchard would practically exterminate the species of parasites normally found attacking the oriental fruit moth in New York. *Ryanex* would have a similar effect when used at

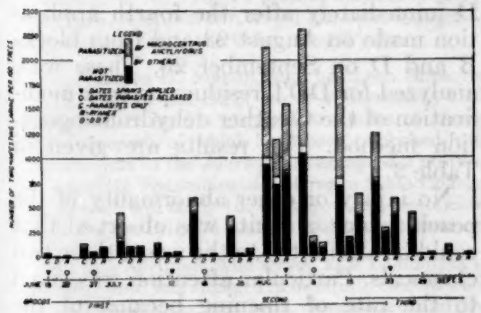

FIG. 2.—Weekly records of populations of oriental fruit moth and parasite larvae showing dates of insecticide treatments and adult parasite releases.

intervals short enough to provide effective fruit moth control. With either chemical both the direct toxic effect of the material and the reduced populations of host insects caused by the treatment, would be important factors in the ultimate loss of parasites from the orchard.

Table 1 is a summary of the data arranged somewhat arbitrarily according to the broods of the fruit moth. The actual number of second-brood parasitized worms per tree may appear too high to substantiate the conclusions stated above until one is reminded of the following facts which can be verified from figure 2. Of the emerged parasites from second-brood larvae 75 per cent of the individuals taken from the DDT block and 60 per cent of those from the *Ryanex* block appeared in the collections taken just previous to the spray application made on August 3. The corresponding figure for the unsprayed block was 26 per cent. The results to be expected from spraying an entire orchard seem quite obvious.

FRUIT INFESTATION.—The entire harvested crop from each of five trees within the blocks and 11 trees in the general orchard areas indicated by E and X in figure 1, was examined for visible evidence of fruit moth injury. The percentage of internal or invisible injury was determined by slicing the externally clean peaches from a random sample equal to one fourth the total crop from the five or six count trees. This figure was then applied to the total number of clean fruits. The result added to the number with visible injury gave the total infestation. All drops were sliced to determine total infestation directly.

The damage to fruit in the X areas between the sprayed blocks proved much more severe than in any other section of the unsprayed area. Therefore X is used as a check for direct comparison with the sprayed areas. Since insect development in E corresponded closely to that in C, the figures obtained from the latter are most valuable when compared directly to those from block E. Slightly smaller trees and more curculio injury account in part for the lower yield in C and E. However, it is not likely that the smaller yield influenced the number of infested fruits per tree since the larval populations as indicated by twig collections remained high in both C and E throughout the summer.

Injury by the second-brood fruit moth was heavier throughout the western New York peach growing area in 1945 than in normal years. The usual hardening of

the twigs in August found many of the abnormally late second-brood larvae still immature. Many of them left the twigs to complete their development in the fruit.

Near the end of the second brood, 2 peaches were picked at random from each tree in the several blocks. From these samples the percentage of fruit moth injury was determined and was applied to the total yield per tree to give figures for comparison with those obtained at harvest. It is of interest to note that larvae removed from these infested fruits, or others collected at the same time from area E, produced 151 adult insects of which 49 were parasites. It is probable that these larvae were parasitized before leaving the twigs. A summary of the fruit infestation at the end of the second brood and at harvest on September 20 and 21 is presented in table 2.

Table 2.—Peach infestation by oriental fruit moth.

Block	Number of Peaches per Tree							Control Efficiency Per Cent
	Infested by 1st & 2nd Brood Worms	Picked		Drops		Totals		
		Yield	Infested	Yield	Infested	Yield	Infested	
E	24	193	137	67	33	260	170	33.3
C	15	141	96	52	25	193	121	52.5
D	3	368	23	55	3	423	26	89.8
B	36	338	142	69	20	407	162	44.2
X	17	462	214	100	41	562	255	0.0

Two suggestions can be given in partial explanation of the extremely high fruit infestation in areas X bounded on two sides by the sprayed blocks. In the first place, an earlier decrease in numbers of succulent twigs occurred throughout the northern half of the orchard. This reduced the larval population in the twigs and may have caused a more rapid migration of larvae to the fruit. Secondly, judging from the effect noted in the sprayed blocks it would appear likely that the adult parasite population could have been greatly reduced in these comparatively narrow areas. In this case the moth population was not lowered correspondingly since the applications of sprays to the adjacent trees did not affect the number of twig-infesting larvae within the X areas themselves. Unfortunately, since the twig collections from X were not separated from the remainder of the general orchard area (E), it is impossible to verify this point further with present data.

The relative efficiencies of the two chemical treatments and the comparisons between them and the unsprayed blocks under the conditions of this experiment are readily seen. It should be emphasized that these fruit counts were made 28 days following the last spray application. During most of this period weather conditions were generally favorable to fruit moth activity. From block D a total of 1840 picked fruits were examined. Of these only 6 showed any visible evidence of fruit moth injury. Of the 465 externally clean peaches from this block which were sliced, only 28 or 6 per cent were found infested. The 23 larvae found in these fruits were all first or second instars whereas those taken from similar fruits from other blocks were in all stages of development. It is quite apparent that DDT continued to provide nearly full protection until the last week before harvest.

Table 3.—DDT residues on peaches.[1]

Block	Date of Sampling	DDT Residues	
		ppm.	grs./lb.
D	Aug. 23	28.3	0.198
D	Sept. 20	7.8	0.054
B	Sept. 20	5.5	0.039

[1] Analyses made by Richard H. Washburn, Cornell University.

Fruit samples were collected from block D immediately after the fourth application made on August 23 and from blocks B and D on September 20. These were analyzed for DDT residues using a modification of the Gunther dehydrohalogenation method. The results are given in Table 3.

No injury or other abnormality of the peach foliage or fruits was observed that could be attributed to the use of these two chemicals. Particular attention was given to the rate of ripening because of the apparent retardation in quinces where DDT was used in 1944. In this test this condition did not become noticeable nor was it found again on quinces with a reduced number of applications.

While making the fruit counts, numerous peaches from block B were found to have varying numbers of the common red spider mite, *Tetranychus telarius* L.,

clustered about the stem end. Large numbers of these mites were found on several trees and in some cases severe injury to foliage was evident. When the trees in this block were graded into 5 categories based upon the degree of spider mite infestation, 76 per cent were found to fall into the heavier three grades. In contrast, 72 per cent of the trees examined in the four rows adjacent to the sprayed block fell into the lightest grade and all others in grade 2. In the western section of the orchard the red spider mite infestation did not develop to the same extent. However, the same relationship existed between the trees within and adjacent to block D. In 1945 this spider mite infestation developed too late to cause concern, but thousands of adults went into hibernation on the tree trunks and under the surrounding debris. The effect of continued use of DDT on this spider mite infestation will be watched with interest.

SUMMARY.—DDT and *Ryanex* were compared with each other, with natural parasitism and with areas where additional parasites were released for the control of the oriental fruit moth in peaches. Their effect upon both twig-infesting and fruit-infesting larval populations and their effect upon parasite populations were included in the study. Four sprays of DDT at 1 pound actual toxicant to 100 gallons applied at 3-week intervals greatly reduced the number of twig-infesting larvae and also the rate of parasitism. *Ryanex* had a comparable effect for a shorter period. The DDT provided superior protection to the fruit. *Ryanex* did not exhibit the residual action of DDT but should provide protection if used at shorter intervals. No injury to foliage or fruit was observed but an infestation of red spider mite appeared late in the season in the DDT blocks.—12-10-45.

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Mr. M. A. Vogel, Entomologist for Dupont, has been transferred from Wooster, Ohio to Yakima, Washington. Mr. Vogel's present address is 106 N 28th Ave., Yakima. Mr. Vogel has been engaged in the study of fruit insects for several years.

Dr. Charles H. Martin, who has been employed on the staff of Dr. H. S. Smith at Riverside, California, where he was engaged in studies of *Macrocentrus*, reports of which have been published from time to time in the *Journal*, has accepted a position as Associate Entomologist at Oregon State College. Dr. Martin will study the biological and insecticidal control of the Oriental fruit moth at his new location.

Dr. Leo Kartman, who served as a Lieutenant in the Army and was engaged in mosquito control work in various stations, has been demobilized and has joined the Bureau of Entomology and Plant Quarantine. He will be attached to the Division of Foreign Plant Quarantines and is to be stationed in Hawaii. Dr. Kartman expects to leave the mainland about the end of May and proceed to Honolulu.

Dr. H. H. Crowell, formerly Senior Lieutenant in the Navy on mosquito control in Central America, has accepted a position with Oregon State College as Assistant Entomologist. One of Dr. Crowell's projects will be a study of the control of *Diabrotica 11-punctata* Man.

Mr. R. G. Rosenstiel, during the war a First Lieutenant in the Army, on mosquito control in the Bay Region of California, has accepted a position as assistant entomologist with Oregon State College. Mr. Rosenstiel will work with nursery insects and the omnivorous leaf tier. Mr. Rosenstiel was employed at Oregon State College in a similar capacity before he entered the army.

Mr. R. W. Every, formerly Associate Entomologist, Division of Grasshopper Control, U. S. Bureau of Entomology and Plant Quarantine, located at Billings, Montana, has accepted a position as Extension Entomologist with Oregon State College. He succeeds Mr. Robt. E. Rieder who has accepted a position with the Shell Oil Company.

New Formulations of Aerosols Dispersed by Liquefied Gases

E. R. McGovran, J. H. Fales, and L. D. Goodhue
U.S.D.A., Bureau of Entomology and Plant Quarantine[1]

After the adoption of the liquefied-gas aerosol method by the armed forces for the control of adult mosquitoes, it was soon learned that the supply of pyrethrum was not adequate for the continued production of aerosols with the high concentration first recommended. The amount of pyrethrins in the formula was reduced from 1.0 per cent to 0.8 per cent and finally to 0.4 per cent, which left the insecticide too weak for practical use against anything but adult mosquitoes. The need for an effective aerosol against flies and other insects stimulated research for substitutes or supplements for the pyrethrum. As soon as the insecticidal value of DDT became known, its possibilities for use in aerosols were obvious and many formulations containing it were tested. The use of combinations of DDT and pyrethrum in aerosols for the control of houseflies and mosquitoes has been discussed by Lindquist *et al.* (1945). Although no specific data on formulas are given, the combination is reported as very promising.

It was soon learned that the particle size of an aerosol also greatly influences its effectiveness. The particle size, in turn, is controlled by the amount and nature of the nonvolatile material in the liquefied-gas solution. The first insecticidal aerosol, as reported by Sullivan *et al.* (1942), contained approximately 2.4 per cent of nonvolatile material. Subsequent work by McGovran *et al.* (1943) showed that when the nonvolatile content was increased to 16 per cent the effectiveness in killing houseflies was much greater. Recently Fales *et al.* (in press) showed that the optimum nonvolatile content was about 15 per cent and that when it was increased to 30 per cent there was a marked decrease in kill. However, observations on particle size have shown that some materials disperse more easily than others so that the nonvolatile content alone is not an accurate gage of particle size. It appears that the optimum nonvolatile matter in aerosols generated with *Freon-12* (dichlorodifluoromethane) may be increased, as one of the better formulas contains 20 per cent. However, the use of much more than 20 per cent in the formulas that have been tested in the available dispensers has resulted in a marked decrease in toxicity.

A large number of formulas were tested in a preliminary way at the Agricultural Research Center at Beltsville, Md. The urgency of the need by the armed forces for aerosols that were effective against flies and mosquitoes, and that could be prepared from materials available in large quantities during the war, was so great that a thorough investigation of each formulation was not practicable. The more promising combinations of materials that were available at the moment were then given more extended tests. The results are reported here with the hope that this information may be useful to manufacturers producing aerosols for civilian use and that it will serve as a basis for research to improve further the effectiveness of insecticidal aerosols.

Test Methods and Materials.—The formulas were tested on houseflies, *Musca domestica* L., and the mosquitoes *Anopheles quadrimaculatus* Say and *Aedes aegypti* L. Adults of these species were released in a Peet-Grady chamber, and subsequently a small amount of aerosol was introduced into the chamber by the pendulum method, or with a laboratory dispenser (McGovran *et al.* 1943) or a modification of it. In the pendulum method the aerosol is discharged against a swinging metal plate with a small slot in it. The width of the slot and the number of times the plate passes through the aerosol stream determine the dosage used. Counts of the paralyzed insects were made 5, 10, and 15 minutes after the aerosol was released. All the insects, both active and inactive, were collected immediately after the 15-minute observation. They were placed in recovery cages with liquid food, and mortality counts were made the next day.

Mortality counts of both species of mosquitoes were made on males and females separately. The mortality data

[1] This work was financed mainly under a transfer of funds recommended by the Committee on Medical Research, Office of Scientific Research and Development, to the Bureau of Entomology and Plant Quarantine.

given are for the females. In almost every instance higher kill of males was obtained, and usually the difference was marked.

The pyrethrum extract used in the aerosol formulations contained 20 per cent of pyrethrins. The DDT used was a purified aerosol grade containing 99 per cent or more of the para-para isomer. The ingredients and formulations tested are listed in tables 1, 2, and 3.

Results.—The data in table 1 show that a marked improvement in the toxicity of pyrethrum aerosols was obtained by adjusting the relative concentrations of pyrethrum extract and sesame oil. The substitution of another synergist (piperonyl cyclohexenone) for sesame oil further improved both the knock-down and mortality.

The data in table 2 were obtained by the free-hand plotting of knock-down and kill results on logarithmic-probit paper. They show a rapid drop in the dosage required to kill 97 per cent of the flies as the concentration of DDT increased up to 3 per cent. The reduction in dosage was much less when the concentration was increased to 5 per cent. The lubricating oil was omitted from the 5 per cent DDT formula in order to add sufficient cyclohexanone to hold the DDT in solution and still keep the nonvolatile content to around 15 per cent. The dosages of the four formulas in table 2 needed to kill 70 per cent of the flies were variable, and the difference between formulas was not so great as at the 97 per cent mortality level, except between the 3 and 5 per cent DDT formulas. The knock-down figures indicate that when combined with pyrethrum DDT does have some additive effect on knock-down.

When tested against *Aëdes aegypti* mosquitoes at 88 mg. per 1000 cubic feet, the 5 per cent DDT formula given in table 2 caused 49 per cent mortality of the females. The 3, 2, and 1 per cent DDT formulas killed 78, 75, and 76 per cent,

Table 1.—Toxicity to houseflies and mosquitoes (*Aedes aegypti*) of pyrethrum extract plus activator in aerosols.

Formulation (in Freon)			Tests on Houseflies			Tests on Mosquitoes	
Pyrethrum Extract	Activator and Other Accessory Material		Dosage per 1000 cu. ft.	Knock-down in 15 min.	Kill in 1 day	Dosage per 1000 cu. ft.	Kill in 1 day
Per cent		*Per cent*	*Grams*	*Per cent*	*Per cent*	*Gram*	*Per cent*
5	Sesame oil	2	4.6	92	52	0.032	44
2		8	4.6	69	53	.037	35
3		9	4.6	82	55		
4		6	4.6	87	71	.033	49
8		8	2.3	87	62		
5	Piperonyl cyclohexenone[2] and an aromatic petroleum solvent	3	1.15	87	72		
		7					

[1] Mosquitoes were exposed 5 minutes in the closed chamber followed by 10 minutes in the chamber while being ventilated at a slow rate. Knock-down in 15 minutes was high in all cases where mortalities are given.
[2] A mixture of two derivatives of piperonyl cyclohexenone.

Table 2.—Toxicity to houseflies of 1 to 5 per cent DDT plus pyrethrum extract in aerosols.

Formulation (in Freon)				Dosage Causing 90 Per Cent Knock-down in 15 Min.	Dosage Causing Mortality in 1 Day of—	
DDT	Pyrethrum Extract	Cyclohexanone	Lubricating Oil		70 Per cent	97 Per cent
Per cent	*Per cent*	*Per cent*	*Per cent*	*Grams per 1000 cu. ft.*	*Grams per 1000 cu. ft.*	
5	1	10	—	[1]	0.8	9
3	1.5	5	5	30	2.0	12
2	1.5	4	6	32	3.1	33
1	1.5	2	8.5	40	2.5	56

[1] A knock-down of 37 per cent was obtained with this formula at a dosage of 4.6 grams per 1000 cu. ft.

Table 3.—Toxicity to houseflies and mosquitoes, *Anopheles quadrimaculatus*, of combined insecticides in aerosols.

Formulation (in *Freon*)				Dosage	Houseflies		Mosquitoes	
Pyrethrum Extract	DDT	Accessory Material		per 1000 Cu. Ft.	Knock-down in 15 Min.	Kill in 1 Day	Knock-down in 15 Min.	Kill in 1 Day
Per cent	*Per cent*		*Per cent*	*Grams*	*Per cent*	*Per cent*		*Per cent*
2	3	Cyclohexanone	5	0.368	24	55	Medium	89
		Lubricating oil (No. 30)	5					
2	3	An aromatic petroleum solvent	15	.325	23	53	Low	77
2	3	An aromatic petroleum solvent	7	.354	30	62	High	88[1]
		Cyclohexanone	3					
2	3	An aromatic petroleum solvent	7	.330	31	75	Low	77
		Methylene chloride	10					
4	1	Deodorized kerosene	8	.532	34	36	High	92
		Pentane	15					
4	3	Xylene	15	.204	11	45	Medium	86
2	0	Gamma benzene hexachloride	1.5	.384	29	71	Medium	91
		An aromatic petroleum solvent	15					

[1] The dosage on mosquitoes was only one-third that used on flies.

respectively, when applied at 100 mg. per 1000 cubic feet. There is an indication that the higher DDT concentration increased effectiveness against mosquitoes but the pyrethrum appears to have been the primary lethal factor.

The results of tests with combinations of pyrethrum and DDT or benzene hexachloride and various solvents are presented in table 3. In all but one of these tests the flies and mosquitoes were exposed simultaneously. All the various formulas were not tested on the same days; so slight differences in toxicity may be due to this variable. In general, all these formulas are high in toxicity, form stable solutions in *Freon*, and are noninflammable when sprayed, but they may have certain other advantages or disadvantages. For example, the price of the constituents may vary, some ingredients have more of an odor than others, and some have more solvent action on rubber and plastics. These formulas are given more as a basis for making practical, effective aerosols for current use than as perfected aerosols.

CARBON DIOXIDE AS A PROPELLANT IN SMALL DISPENSERS.—Tests were made with carbon dioxide-propelled aerosols packed in soda-syphon cartridge-type containers (Fig. 1). These containers discharged the entire contents when the tip was broken off. The aerosol solution contained 1 per cent of pyrethrum extract, 5 per cent of sesame oil, 44 per cent of kerosene, and 50 per cent of a 1 per cent DDT solution in acetone. From 6 to 7 grams of this solution was placed in each cartridge along with 1.8 to 2.4 grams of carbon dioxide. When one of these cartridges was discharged in a 1000-cubic-foot room, 95 per cent of the flies and a high percentage of *Anopheles quadrimaculatus* mosquitoes were knocked down in 10 minutes and 100 per cent of both flies and mosquitoes were killed. The aerosol produced was inflammable. Noninflammable *Freon* aerosols have also been packaged in containers of this type.

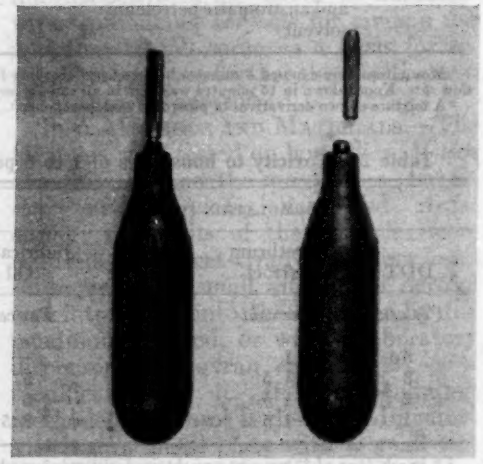

FIG. 1.—Soda-syphon cartridge-type aerosol bulbs (one-half actual size). Left, loaded dispenser; right, discharged dispenser with tip broken off.

SUMMARY.—Tests of various liquefied-gas aerosol formulas against houseflies and mosquitoes were made in a Peet-Grady chamber. Aerosol formulas greatly improved in toxicity over the original formula have been developed by increasing the nonvolatile content and by adding more sesame oil, another synergist (piperonyl cyclohexenone), DDT, benzene hexachloride, and suitable solvents. Carbon dioxide was satisfactory as a propellant in small containers.—1-10-46.

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DDT Preparations for Control of the Pea Aphid[1]

L. P. DITMAN, *Maryland Agricultural Experiment Station, College Park*[2]

Experiments with DDT in liquefied gas aerosols during 1944 showed DDT to be a highly effective insecticide against the pea aphid. Because of the shortage of satisfactory rotenone-bearing insecticides and the demand by canners for a more effective aphid control, efforts were made to secure as much information as possible on the use of various other DDT preparations against this insect. The work reported here is concerned chiefly with DDT sprays, although a few observations on the effectiveness of dusts are included. These results were obtained from experimental plots and from the use of DDT in the hands of growers.

OBSERVATIONS AT EASTON.—A local canner, who sprays for aphid control, applied a dry-mixed preparation containing 33.3 per cent DDT, 8.3 per cent sodium lauryl sulfate, and 58.3 per cent pyrophyllite in water suspension. At first the material was used at the rate of 3 pounds to 125 gallons per acre; later the rate was increased to 4.5 pounds. The kill of aphids was generally unsatisfactory, and this canner discontinued operations after treating 200 acres. An estimation of aphid reduction on treated areas as compared with untreated areas showed less than 50 per cent. The DDT used in the suspension was not finely ground and contained many coarse particles which may have contributed in part to the poor results.

Three plots an acre or more in size were treated under the author's direction with DDT emulsions. The first plot was sprayed on April 27 with a xylene-DDT emulsion (xylene 681 cc. DDT 227 gm. *Triton X-100* 227 cc.) at the rate of 8 ounces of DDT per acre. There was a cold east wind of 25 m.p.h. velocity and a drizzle of rain at the time of treatment. The treated plot averaged 2.5 aphids per sweep just before the treatment was applied, while an adjacent plot which was left untreated averaged 13.1 aphids per sweep. On May 9, 12 days later, the population averaged 48.5 aphids per sweep on the untreated plot while on the treated plot there were 3.2 aphids per sweep, representing a reduction of 93.4 per cent.

The other two plots, which were in another field, were sprayed on May 9, one with an emulsion containing *P.D. 544-B*[3]

[1] Scientific Paper No. A 113, contribution No. 1993 of the Maryland Agricultural Experiment Station, Department of Entomology.

[2] F. F. Smith of the Bureau of Entomology and Plant Quarantine, U.S.D.A., and D. F. Starr, formerly associated with the same organization aided in some of the field work. W. E. Hall, of the Shell Oil Co., prepared and assisted in the application of the various ACX emulsions.

[3] The petroleum solvents *P.D. 544-A*, *P.D. 544-B*, and *P.D 544-B* (treated) referred to in this paper are methylated naphthalenes and products of the Socony-Vacuum Oil Co., New York. The treatment of *P.D. 544-B* was of a chemical nature not known to the author.

390 cc., DDT 227 gm., and *Triton X-100* 20 cc., and the other with an emulsion containing xylene 450 cc., DDT 227 gm., and *Triton X-100* 20 cc. These were diluted with 125 gallons of water, the amount being applied per acre. A sample population of the field showed an average of 225.6 aphids per sweep at the time of treatment. On May 11 there were 96 aphids per sweep in the centrally located check plot, 16 per sweep on the xylene-emulsion plot, and 8.5 per sweep on the *P.D. 544-B*-emulsion plot, representing reductions of 83.3 and 91.1 per cent, respectively, from the check plot.

The aphid population in this field had reached its peak before May 9 and was rapidly declining at the time treatments were made. The treatments were applied much too late; the vines were already badly damaged by the previous high aphid population, and accurate observations on insecticidal injury to plants could not be made.

RIDGLEY SINGLE-PLOT EXPERIMENTS.—Two emulsions were applied to single plots approximately 1 acre in size on April 28. One emulsion was made with *Aromatic Petroleum Solvent 202* (proportions: *APS-202* 681 cc., DDT 227 gm., *Triton X-100* 227 cc.), the other with ethylene dichloride instead of *APS 202* but in the same proportions. Both emulsions were diluted so that approximately 8 ounces of DDT was applied per acre. The aphid population at the time of treatment averaged 162.6 per sweep. On May 8, 10 days after treatment, the *APS-202*-emulsion plot had an average of 1.8 aphids per sweep and the plot treated with ethylene dichloride emulsion had an average of 1.6 per sweep. The reduction based on the check-plot population was greater than 99 per cent, but severe plant injury resulted from both treatments. The plots turned brown a few days after treatment, but new growth appeared later and the yield of shelled peas from the *APS*-emulsion plot was about equal to that from the untreated portions of the field, while the ethylene dichloride emulsion plot yielded 38 per cent more.

RIDGLEY REPLICATE-PLOT EXPERIMENTS.—Five spray treatments, including two DDT emulsions, two DDT suspensions, and a standard treatment of ground derris root, were applied to plots approximately 6 square rods in size in randomized blocks replicated four times. Descriptions of treatments and effects on population and yield are given in table 1. The superiority of DDT emulsions over DDT and ground derris root suspensions for control of the pea aphid is clearly demonstrated. It was of particular interest to the author that the yields of the emulsion-treated plots were so high despite considerable plant injury. The emulsion

Table 1.—Results of DDT spray treatments for control of pea aphid on experimental plots at Ridgley, Maryland. Treatments applied May 8.

TREATMENTS AND AMOUNTS OF MATERIALS IN 100 GAL. OF WATER[1]	AVERAGE NUMBER OF APHIDS PER SWEEP			REDUCTION PER CENT OF CHECK	YIELD POUNDS SHELLED PEAS PER ACRE
	May 8	May 11	May 19		
DDT 227 gm. *P.D. 544-A* 368 cc. *Triton X-100* 18.7 cc.	32.4	3.6	15.3	96.2	3580
DDT 227 gm. *P.D. 544-B* 395 cc. *Triton X-100* 18.7 cc.	25.5	2.1	12.4	96.9	3553
DDT 227 gm. Kaolin 227 gm. (very fine suspension)	34.5	15.0	131.9	67.5	2950
DDT 227 gm. Pyrophyllite 396 gm. Sodium lauryl sulfate 57 gm. (relatively coarse suspension)	37.5	19.2	208.9	48.5	2789
Ground derris root 3 lb. (6.3% rotenone) Sodium lauryl sulfate 4 oz.	45.1	25.7	189.0	53.4	3238
Check	29.2	44.3	406.0		2618

[1] DDT was applied at the approximate rate of 0.7 lb. per acre on all DDT-treated plots.

containing *P.D. 544-A* was particularly injurious. On May 11 the pea leaves were greenish brown and brittle, stems and sepals were brown, and plants appeared to be stunted. On May 19 new growth appeared normal, but injury was still evident in the lower portions of the plants. The *P.D. 544-B* emulsion caused some burning of leaf margins and growing tips but not nearly so much as the *P.D. 544-A*.

RIDGLEY SMALL-PLOT PHYTOTOXICITY TESTS.—Two series of small plots, each approximately 5 feet square, were sprayed with a compressed-air hand sprayer with DDT in 7 solvents with varying amounts of 3 emulsifiers. Plants were sprayed until thoroughly wet.

In these tests amounts of emulsifier in excess of the minimum required for emulsification caused plant injury. *Triton X-100* was less injurious to plants than *Igepal C.A.* and *Tween 80*. Of the solvents tried xylene and *Velsicol A.R. 60* appeared to be the safest on foliage. *P.D. 544-A*, *P.D. 544-B*, and *P.D. 544-B* (treated) caused plant injury with minimum amounts of emulsifier (*Triton X-100*). Ethylene dichloride and tetrahydronaphthalene emulsions with excessive amounts of emulsifier present caused plant injury. A suspension of DDT made by adding an acetone solution to water was apparently not injurious to peas.

LAYTONSVILLE EXPERIMENTS.—A number of DDT emulsions were sprayed on both wrinkled and Alaska peas. Two proprietary materials (*Miller's 30 per cent DDT Liquid Insecticide* and a rotenone preparation, *Tubicide*), two ethylene dichloride emulsions, and several aliphatic petroleum oil emulsions (*ACX Nos. 35, 36, 37, 39 and 40*)[1] were applied. Emulsions containing rotenone and *Tanatox*[2] were included in the last group. All treatments were applied on May 23 to single plots an acre or more in size. Descriptions of treatments and results are given in table 2. Fields were examined on May 28, at which time no foliage injury was

[1] The various *ACX* solvents referred to in this paper are aliphatic petroleum oils which were supplied by Shell Oil Co., New York.
[2] A synthetic insecticide provided by the Shell Oil Co.

Table 2.—Results of DDT spray treatments for control of pea aphid on experimental plots at Laytonsville, Maryland. Treatments applied May 23.

Treatments and Amounts of Materials per 100 Gal. of Water	Pounds of Toxicant per Acre[1]	Average Number of Aphids per Sweep		Reduction, Per Cent of Check
		May 23	May 28	
Treatments on Alaska Peas				
A Untreated check		887.4	1058.0	
B *Tubicide* 2 qts.		417.0	219.7	79.2
C DDT 112.5 gm; ethylene dichloride 222 cc; *Triton X-100* 62.5 cc	.37	307.2	80.5	92.4
D DDT 140 gm; ethylene dichloride 222 cc; *Triton X-100* 62.5 cc	.46	267.7	72.5	93.1
E DDT 195 gm; *Shell Horticultural Spray Oil* 5 qts. *Triton B-1956* 125 cc.	.64	283.7	199.4	81.2
Treatments on Wrinkled Peas				
1 Same as E	.64	45.8	13.5	93.4
2 *ACX 35* 5 qts. containing 142 gm DDT; emulsifier not known	.47	61.8	31.3	84.1
3 *ACX 36* 5 qts. containing 142 gm DDT; emulsifier not known	.47	48.0	16.0	92.2
4 *ACX 39* 5 qts. containing 213 gm *Tanatox;* emulsifier not known	.70	37.8	176.0	13.9
5 *ACX 40* 5 qts. containing 19 gm. rotenone; emulsifier not known	.06	49.8	211.2	3.2[2]
6 *ACX 37* 1 gal. containing 94.5 gm. DDT; emulsifier not known	.31	61.3	18.2	91.1
7 *ACX 37* 2 gals. containing 189 gm. DDT	.62	90.6	9.2	95.5
8 Untreated check		91.2	204.5	
9 *Miller's 30% DDT Liquid Insecticide*	1.03	53.0	7.7	96.2
10 Same as C	.37	33.3	9.8	95.2
11 Same as D	.46		11.7	94.3

[1] Refers to DDT, rotenone, or *Tanatox*.
[2] Increase over check.

evident on any of the Alaska plots. Occasionally, however, there was very slight leaf burning in the wrinkled pea plots treated with *ACX 36*, *ACX 39*, and *Miller's 30 per cent DDT Liquid Insecticide*, although this injury was not considered to be of consequence. Treatments on the Alaska peas were applied too late, and considerable injury had already resulted from the feeding of aphids before treatment. The sweet or wrinkled peas were treated at what was thought to be the proper time. Yields were not taken on individual plots, but the field as a whole yielded 2.25 tons of shelled peas per acre, the entire field with the exception of the check plots having been treated.

Commercial treatment of over 100 acres of peas in Montgomery County with *Miller's 30 per cent DDT Liquid Insecticide* gave results considered by the canner to be quite satisfactory and superior to past years' results with various rotenone dusts and sprays.

OBSERVATIONS ON DDT DUSTS.—One observation was made in a commercial field of peas on which a 5 per cent dry-mixed DDT dust and *V-33*[1] rotenone dust had been applied on May 15. About 40 pounds of each dust was applied per acre. Examination 5 days after treatment showed an average of 107.2 aphids per sweep on the DDT-treated peas, 134.0 on *V-33*-dusted peas, and 281.6 on the untreated peas. Based on the untreated check, this was 61.9 per cent reduction for the DDT treatment and 52.4 per cent for the rotenone treatment.

A dust containing 1 per cent of DDT, made by atomizing a non-volatile solution of DDT in *Velsicol A.R.-60* into the talc carrier in the mixing process, was applied to a 1 acre plot of wrinkled peas on May 31. A number of aerosol treatments were made at the same time, and untreated areas were left in the center and on the far side of the field from the dusted plot. The aphid population was 81.1 per sweep on the dusted plot before treatment and 101.3 on the untreated area. Five days after treatment the untreated plot averaged 70.3 aphids per sweep while the dusted plot averaged 23.4, a reduction of 66.7 per cent. The author does not attach much significance to these results, because of the variation in intensity of aphid population over the field and the great distance between treated and untreated plots.

A field of Alaska peas in Carroll County which had been dusted with a similar 1 per cent DDT dust was examined several days after treatment. Very few aphids were present and excellent results had apparently been obtained. The field was said to have been heavily infested at time of treatment.

SUMMARY.—In the experimental plots and commercial applications described in this paper, dry-mixed DDT dust and suspensions of DDT in water did not give satisfactory control of the pea aphid. All of the various DDT emulsion sprays tried gave excellent kills of the pea aphid but some formulations caused serious plant injury. This injury was attributed (1) to the direct action of the solvent or the emulsifier on the plant, and (2) to excessive amounts of one or the other of these ingredients. Emulsions of DDT in xylene, ethylene dichloride, and the aliphatic petroleum oils (the *ACX* series in table 2), in which minimum amounts of solvent and emulsifier were used, appeared to be the safest of the treatments used on pea foliage. In limited phytotoxicity tests *Velsicol AR-60* appeared to be a satisfactory solvent. *Triton X-100* was the most satisfactory emulsifier tested. Apparently a safe formula for spraying consists of xylene or ethylene dichloride 390 cc., DDT 227 gm., and *Triton X-100* 20 cc. This amount is sufficient for 1 acre of peas and should be diluted with enough water to make the amount of finished spray being applied per acre. One-half pound of DDT applied per acre in a water emulsion appears to be ample for pea aphid control and in tests reported was superior to *Tubicide*, a proprietary rotenone emulsion, at twice its recommended concentration, and to the standard spray of ground derris root.—2-2-46.

[1] Product of the Miller Chemical and Fertilizer Company, Baltimore, Md.

Particle-Size Distribution in Liquefied-Gas Aerosols

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The particle size of insecticidal aerosols produced by releasing liquefied-gas solutions has been the subject of inquiry since the method of dispersion was first described (Goodhue 1942). Most of the literature on the determination of particle size of aerosols is controversial, and few methods apply to such unstable systems as aerosols. As a consequence only the settling rates of these aerosols had been determined in this laboratory up to the time of the work to be described.

The entomological data that were being obtained on insecticidal aerosols indicated that very fine particles were less effective than larger ones. Therefore, it was thought desirable to correlate these data with information on particle size in the hope of obtaining a means of evaluating the effectiveness of an aerosol without actual biological tests.

It was obvious that the concentration of the solute in the liquefied-gas solution used to produce the aerosol was directly related to the particle size; that is, as the concentration increased the particle size of the aerosol also increased. This led to an investigation to determine the correct amount of nonvolatile solute required to produce an aerosol having the most effective particle size.

McGovran *et al.* (1943), using a capillary nozzle, tested aerosols containing up to 16 per cent of nonvolatile matter on houseflies, *Musca domestica* L., and found the highest concentration to be the most effective when compared on the basis of equal dosages of insecticides. Later Fales *et al.* (1946), studying concentrations of solute as high as 30 per cent, placed the optimum at 15 per cent. Some of the solutions used in this investigation were chosen to produce the aerosols for these particle-size determinations.

Unlike particles in kerosene-base sprays, the particles forming these insecticidal aerosols generally do not diminish in size after they are formed, because only nonvolatile residues remain after the liquefied gas has evaporated. Therefore, elaborate methods of measuring the droplets immediately after the formation are not necessary. A microscopic method of observing and measuring particles collected on a suitable medium should be suitable for these aerosols.

DESCRIPTION OF METHOD.—A microprojection unit was set up similar to the one described by Gooden & Goodhue (1939). The screen on which the particles were projected was divided into squares 5 cm. on a side, and they were further divided into 25 squares with a 1-cm. edge. The microscope was equipped with a 10× eyepiece. A 10× objective was used for the lower magnification and a 43× for the higher power. The microscope was used in an upright position, and a totally reflecting prism was attached to the eyepiece to reflect the image onto a vertical screen. The plane substage mirror was used to direct the light beam into the microscope, and the top section of the substage condenser was removed. The lamp was 14 inches from the microscope. The light source first used was a 32-candle power automobile headlight, mounted in an ordinary focusing microscope lamp housing having a condenser and an iris diaphragm. This lamp is inexpensive and can be operated at nearly 10 volts, instead of 6 to 8 volts for which it is rated. It gives a concentrated brilliant light with a life of about 8 hours. Later an arc light with a condenser and water cell was used, but very little more contrast between the drops and the screen could be obtained.

Two problems presented themselves—how to obtain a suitable surface on a slide on which to collect the sample, and how to get a representative sample of the aerosol.

The surface on the slide must be oleophobic to prevent irregular spreading of the particles and keep the deposited particles in the form of lenses until measurements could be made; furthermore, the angle of contact must be constant. After several methods of preparing these slides had been tried, the following procedure was found to give a very satisfactory surface:

(1) Clean slides by placing them in a hot acid bath, consisting of sulfuric acid

with a few milliliters of nitric acid added.

(2) Rinse thoroughly with tap water.

(3) Rinse thoroughly with distilled water.

(4) Rinse in alcohol.

(5) Dip into a 1 per cent alcoholic solution of mannitan monolaurate.[1]

(6) Dry by gentle heating over a desk lamp.

(7) Polish with a clean towel.

Apparently the amount of mannitan monolaurate required to render the slide oleophobic cannot be removed by rubbing with a towel. It was found advisable to prepare slides at least 24 hours before using, but not more than a week in advance. Sometimes static electricity on freshly prepared slides causes irregular patterns of droplets.

For obtaining a uniform sample of aerosol a settling chamber was set up. It consisted simply of a glass jar 29 inches high and 16 inches in diameter inverted on a table, 32 inches high, in the center of which a 1-inch hole had been drilled. The jar was placed exactly over the center. A semicircular hole was cut in a 1-inch board which was nailed to the top of the table as a guide for the jar. Three microscope slides were placed on clean paper under the jar equidistant from the center and from each other.

Experimentation proved that the best sample could be obtained by holding the aerosol bomb in a large clamp pivoted on a ring stand attached to the under side of the table. The valve was opened, and while spraying, the bomb was swung under the hole to introduce the aerosol up into the jar without the large droplets being formed at the beginning and the end. Two hours were allowed for the particles to settle.

Some types of nozzles are more variable than others. The results can be duplicated most easily with a capillary 0.017 inch in diameter and 4 inches long as a nozzle. Except for the study of different nozzles, this capillary was used throughout.

To facilitate the measurement of the particles as observed on the screen, the following size groups, in microns diameter, were set up: Below 2, 2–5, 5–10, 10–20, 20–30, 30–40, 40–50, 50–75, 75–100, 100–125, 125–150, etc. The numbers of particles in these ranges were tabulated. The general procedure was to count under high power 0.02 of a field for the particles under 2 microns and 0.25 of the field for those particles between 2 and 5, in each of 3 fields; 3 whole fields between 5 and 10 microns, 9 fields in the four ranges from 10 to 50 microns, and 15 fields under low power for the ranges above 50 microns. Each field under low power was 19.4 times as large as a field under high power. This area is large enough to give a representative sample of the widely scattered large droplets. All these data were then reduced to the terms of 3 fields on each of the 3 slides and totaled.

The spreading coefficient of the droplets was next determined by measuring the diameter and the focal length of several drops and the refractive index of the materials composing them. On the assumption that the planoconvex lenses are sections of a sphere, the spreading can be calculated from the law of lenses.

After the spreading coefficient (ratio of diameter of droplet to diameter of lens) had been obtained, the average radius, and hence the volume of insecticide, in each range can be calculated. The arithmetic mean radius was used. From the total volume the percentage in each range was calculated and plotted as cumulative frequency curves. When the volume instead of the number distribution of the particles is used, the fine particles affect the results very little. This is appropriate to insecticide work, since very small particles do not contribute much to the mortality.

The distribution of the sample over the floor of the chamber was first studied by placing slides in concentric rings around the hole where the sample was introduced. The distribution was uniform and well within the experimental error of the method. Formula 195, table 1, was used and the results are shown in figure 1. This error should never exceed ± 5 per cent from the mean in any range. Two or more runs were made on all samples.

EFFECT OF CONCENTRATION OF NONVOLATILE MATERIAL.—The effect of the concentration of nonvolatile matter was studied by using four solutions of pyrethrum and sesame oil (Fig. 2) and four solutions containing DDT and dibutyl phthalate (Fig. 3) both in dichlorodifluoromethane.

It will be noted that the difference be-

[1] First used for this purpose by L. D. Anderson, formerly of the Bureau of Entomology and Plant Quarantine.

Table 1.—Composition of various aerosol solutions on which the particle-size distribution of the aerosol was determined.

(Figures in per cent by weight)

CONSTITUENT	No. 179	No. 193	No. 195	No. 197	No. 198	No. 199	No. 215
Pyrethrum	2	2	2	2	2	2	2
DDT	3	3	3	2	3	3	—
Sesame oil	—	—	—	—	—	—	8
Cyclohexanone	5	—	—	—	3	—	—
Lubricating oil	5	—	—	—	—	—	—
Aromatic petroleum solvent	—	7	7	10	7	15	—
Propylene oxide	—	—	5	—	—	—	—
Methylene chloride	—	10	—	—	—	—	—
Dichlorodifluoromethane	85	78	83	86	85	80	90

tween No. 23 and No. 24 is not great. In dilute solutions doubling the concentration should increase the particle size by the $\sqrt[3]{2}$, or only 1.26. As the concentration is increased beyond the range of dilute solutions, other factors, such as surface tension, viscosity, and decreased energy from less liquefied gas, make this difference much greater. Entomological data (McGovran *et al.* 1943) show that the most effective mixture of pyrethrum and sesame oil is No. 26, containing 16 per cent of nonvolatile material.

Dibutyl phthalate as a nonvolatile liquid gives many small particles, as shown by the curves in figure 3. Entomological data indicate the most effective concentration of nonvolatile material to be 15 per cent as in No. 99, although it has a smaller average particle size than No. 26 (Fig. 2). There may be an optimum particle size for each type of nonvolatile liquid according to the degree of dispersion that is obtained.

EFFECT OF THE NOZZLE.—To a considerable extent the size of the particles is dependent on the type of nozzle. Four different types of nozzles in use on commercial aerosol bombs were studied, as follows:

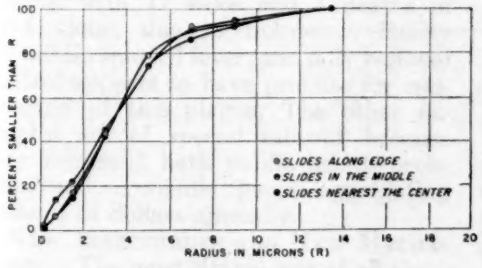

FIG. 1.—Uniformity of distribution in sampling chamber using formula 195.

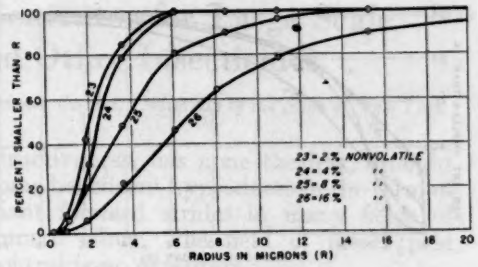

FIG. 2.—Effect of non-volatile content on particle size using pyrethrum extract and sesame oil 50-50.

(1) A small copper cup having a 0.012-inch hole filled with cotton for a filter.
(2) A 0.017-inch I. D. capillary 4 inches long.
(3) A valve-and-nozzle assembly in which the aerosol solution is conducted through the threads on the valve stem and out a 0.02-inch hole.
(4) A 0.008-inch hole in a tip preceded by a piece of close-fitting corrugated rod as a strainer.

The effect of the nozzle when solution No. 25 was used is shown in Fig. 4. Some supporting data indicate that a better dispersion is obtained when small bubbles of vapor are formed before the liquefied-gas solution is discharged at the nozzle.

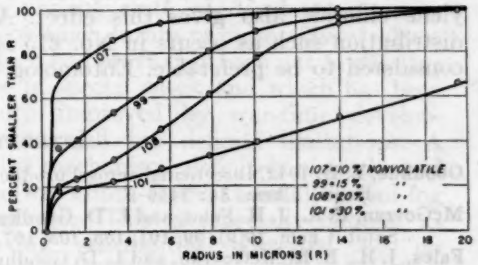

FIG. 3.—Effect of non-volatile content on particle size using dibutyl phthalate and DDT, 14-1.

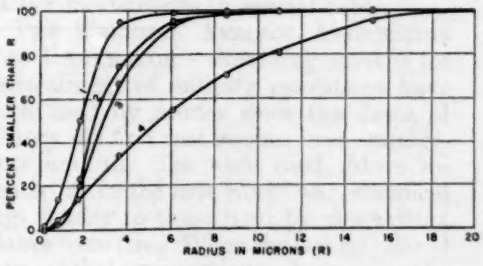

FIG. 4.—Effect of nozzle on particle size of aerosols formed by No. 25.

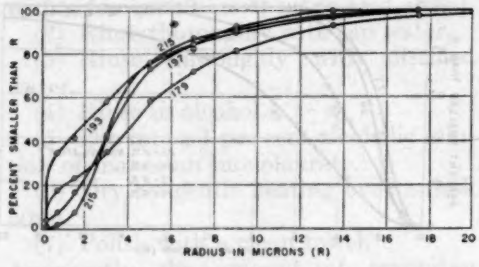

FIG. 5.—Particle size distribution of some aerosol formulations.

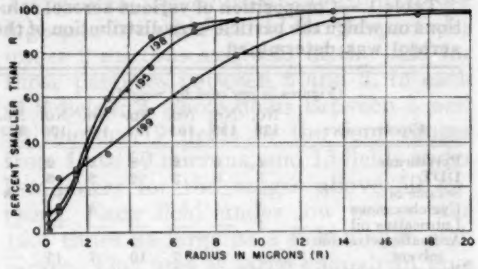

FIG. 6.—Particle size distribution of some aerosol formulations.

Nozzle 4 tends to eject a liquid stream; at least, no ebullition occurs until the solution is expelled. With the other types there is a drop in pressure which starts some boiling before the solution is ejected. Gas that is entrapped in small places starts ebullition and improves the degree of dispersion. This was clearly shown in a study of small bulbs blown in glass capillaries.

EXPERIMENTAL AEROSOL SOLUTIONS.—The solutions described in table 1 were studied to show the effect of different constituents on the particle size. The results are shown in Figs. 5 and 6. It is obvious that certain liquids are more easily dispersed than others. Those containing a high-boiling aromatic petroleum solvent, composed mostly of alkylated naphthalenes, form many small particles. Methylene chloride also gives this effect. A distribution such as occurs in No. 215 is considered to be preferable. Entomological data indicate that the aerosols having the most material in drops between the radii of 2 and 10 microns are most effective, when tested in a nearly static atmosphere on free-flying insects.

SUMMARY.—A method of determining the particle size of liquefied-gas aerosols has been described. The particles were collected on oleophobic slides and measured by projecting them on a calibrated cross-hatched screen. The results in volume per cent are plotted as cumulative frequency curves. The particle size of an aerosol increases as the concentration of nonvolatile material in the liquified gas increases. The type of nozzle affects the particle size. Nozzles allowing some drop in pressure and partial ebullition before the liquid is expelled are the most efficient. The particle-size distribution curves for some aerosols of different compositions are given.—1-9-46.

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The Thermal Aerosol Fog Generator for Large Scale Application of DDT and Other Insecticides

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Control of some insect pests awaits new tools. Expedients of many kinds are employed for control of insect pests; but, regardless of diversity, such measures usually depend upon rendering the environment in some manner effectually inimical to the welfare of the pest, with as little attendant harm as possible to human interests.

Commonest among such measures are the lethal factors variously introduced into the environment in the form of insecticide poisons. Newer and newer insecticides, and ever newer mechanisms for their application have progressively extended our mastery of insect pest control problems; but several groups of such problems have long continued to be baffling for lack of suitable insecticides, or of mechanisms appropriate for their effective distribution or usable within the limits imposed by physical and economic practicability.

Notable among the pending, as yet unsolved, and particularly baffling insect pest control problems are those which apparently will require large scale or regional coverage with appropriate insecticides.

Well known examples are those special problems which are concerned with the control within practical and biologically sound limits of such pests as blackflies, punkies, mosquitoes, sandflies and similar noxious insects, and of the tick and similar vectors of Rocky Mountain spotted fever and other diseases.

All of these still unsolved problems are of special interest in New York. The last, because in a single county there had been up to the end of 1944, 82 cases and 14 deaths, with 17 cases and 4 deaths in 1944 alone, due to tick-borne Rocky Mountain spotted fever; and only regional control appears to have promise for suppression of this plague. The other examples are of special interest because they represent both public health problems and economic losses aggregating millions of dollars annually.

New Insecticides and New Mechanisms.—The most titanic war of all time, notwithstanding all its horrors and destructiveness, has none the less, brought some beneficent byproducts in the form of giant forward strides in many fields of human effort. The field of insect pest control is no exception.

The remarkable new insecticides DDT, gammexane, and others that appear to be in sight, which have come to us coincident with and largely if not wholly products of, the war effort, promise greatly to extend many horizons of practicable insect pest control beyond the limits hitherto imposed by even the best combinations of formerly available mechanisms and insecticides.

New mechanisms, also developed in the war effort, promise likewise to contribute more largely to such extension of pre-war horizons of insect pest control through making possible fuller use of the unique potentialities of our new war-contributed insecticides and even of pre-war insecticides, than would previously existing mechanisms.

For the hitherto largely impracticable large scale or regional pest control operations, the helicopter, while of little use in its present state of development, may have much future promise. The airplane, which had previously been put to effective use in special cases, and which has been much improved by war-time developments, still has definite limitations. A third mechanism, definitely a product of the war effort, is the thermal aerosol fog generator. This is especially notable as having possibilities possessed by no other device in the same degree, and as showing promise of becoming a valuable supplement to, or even of displacing, earlier mechanisms in special fields.

The Thermal Aerosol Insecticide Fog Generator.—Screening smokes for concealment of military operations have been used by armies since the dawn of history. At first real smokes from smudgepots and the like were used. More recently, as in the first world war, chemical fogs similar to those used by sky-writing planes were tried. When the last war flared into global proportions, however, the growing need for screening smokes quickly

outran the available supply of previously used smoke-forming chemicals and new scources of screening smokes had to be devised.

Everyone is now familiar with the basic contribution made by Langmuir and his associates, by which heated oil is dispersed in air as microscopic droplets, the optimum diameters of which are on the order of a half to three-quarters of a micron, or about one sixty-thousandth of an inch.

Several modifications of this idea have been developed by various manufacturers for military use. Very early, the idea was advanced that such smoke generators might be useful for the dispersion of DDT and other oil-soluble insecticides but tests quickly disclosed two handicaps, namely:

1. The optimum particle size for screening smokes is that diameter which will give maximum scattering of transmitted light, and which at the same time will long remain suspended in the air and long retain its screening value as it spreads and becomes more dilute. Such screening fogs are not well suited for the application of insecticides because they rise to excessive heights, drift far, deposit slowly, and thus are uncontrollable and wasteful.

2. The particle size in such an oil fog is determined in part by the temperature of the oil and the higher temperature employed to produce the screening fog will decompose substantial proportions of the dissolved insecticides.

In consequence, several modifications of the oil fog generator have been made, some independently by commercial agencies and some by scientific laboratories under contracts sponsored by War Agencies, to correct these defects through redesigning the machines to operate at lower temperatures, and to deliver a larger fog particle, the diameter of which might be controlled at will and held within narrow limits.

During the past season (1945) the authors have been privileged to arrange, and to participate in a fairly comprehensive series of tests with two of the leading mechanisms of this type, resulting in a rather extensive examination of this method of applying insecticide materials, and of its general possibilities and limitations.

These explorations have demonstrated that the thermal aerosol fog generator unquestionably has promise of unique value in many special fields of pest control work, and merits careful experimental study by entomologists and plant pathologists generally. The present preliminary report is designed to bring this fact to their attention.

INDIVIDUAL STUDIES UPON WHICH THIS REPORT IS BASED.—The projects noted will be reported individually in subsequent articles.

The two types of generators used in these studies are:

1. *The Hochberg-LaMer Thermal Aerosol Insecticide Fog Generator* Plate I, 1, is based upon modification designed for two or more of the earlier military oil-fog screening "smoke" generators under a contract between the Central Aerosol Laboratories at Columbia University, and Division 10, National Defense Research Committee of the National Research Council Office of Scientific Research and Development.

The Hochberg-LaMer machine, a so-called "wet" type aerosol fog generator, as used in this series of field experiments employed water and an oil solution of the insecticide (DDT in this case), and depends upon superheated steam under controlled temperature and pressure to break up the oil solution into droplets of the desired particle size. The machine is designed also to disperse emulsions or suspensions.

This machine was provided, together with experimental materials and personal services by Dr. V. K. LaMer and was operated in two projects of this series under his supervision by several of his associates.

At that time, the prevailing rules of military secrecy prohibited any photographs of the machine in action. The photograph shown was provided subsequently through the courtesy of Dr. LaMer.

2. *The Todd Thermal Aerosol Insecticide Fog Generator*, characterized by its pro-

EXPLANATION FOR PLATE I

PLATE I, 1.—Hochberg-LaMer thermal aerosol fog generator. 2.—Original Todd thermal aerosol fog generator. 3 & 4.—Blackfly control experiments at Old Forge, N. Y. 5 & 6.—Blackfly control experiments at Blue Mountain Lake, N. Y. 7 & 8.—Punkie control experiments at AuSable Club, St. Huberts, N. Y. 9, 10, 11 & 12.—Fly control at Cimarron Dude Ranch, Peekskill, N. Y.

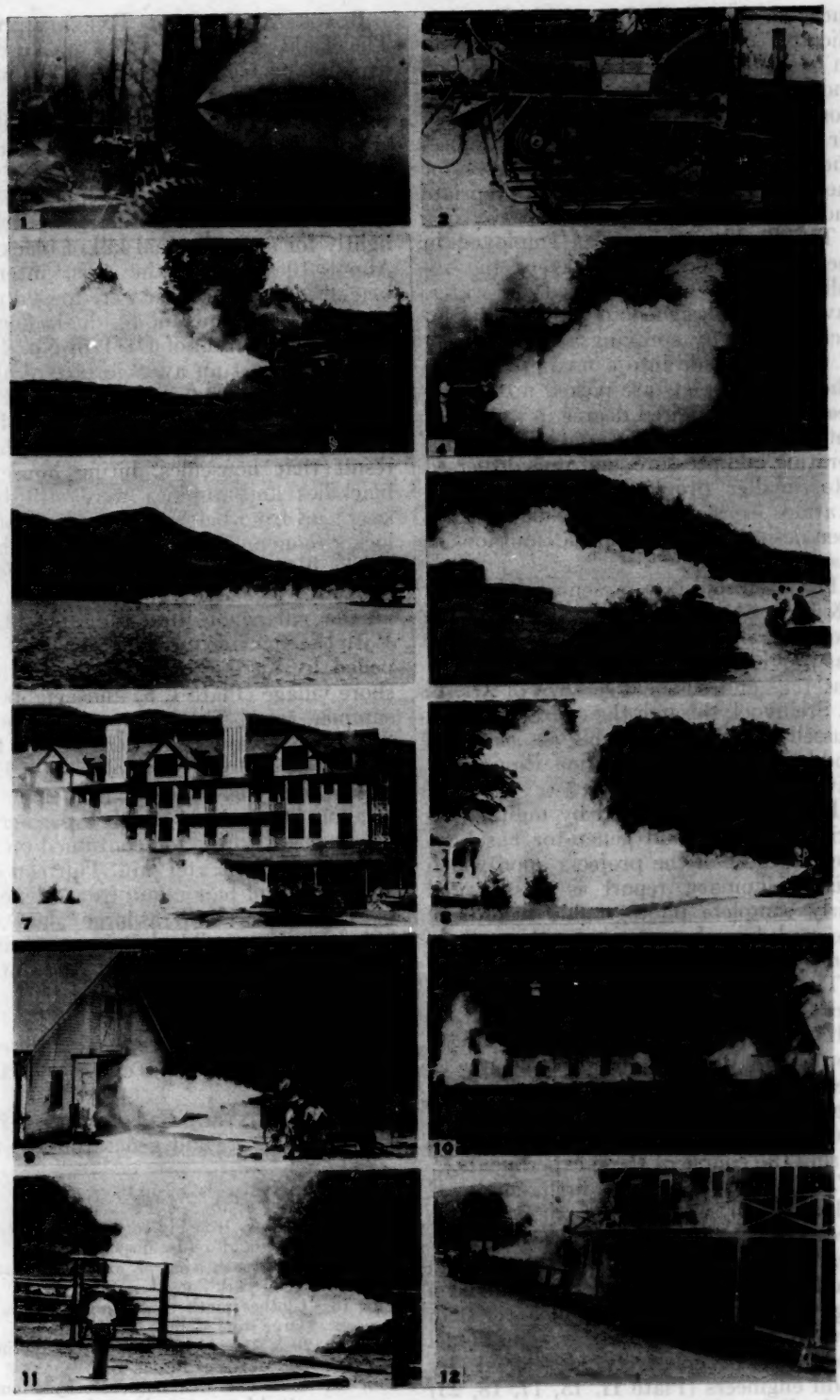

PLATE I

ducer as the "Todd Insecticide Fog Applicator" or *TIFA*, is an outgrowth from an oil-fog generator which was developed and manufactured by Todd Shipyards Combustion Equipment Division, largely for use by the Navy, and was subsequently modified by its originators for the purpose of delivering an appropriate and controlled particle size.

The Todd generator as employed in these field experiments was of the so-called "dry" type and used no water, having been designed to produce the insecticide fog by spraying an oil solution of the insecticide into a mixing chamber where the droplets are picked up by and heated to the desired degree in a blast of hot air maintained at a controllable temperature and pressure, and thus dispersed into smaller droplets when discharged at atmospheric pressure. This machine has been designed also to disperse emulsions or suspensions.

For the projects represented by Plates I & II, 2–24, one or another model of the progressively developing Todd generator was provided, together with experimental materials and personal services of Mr. F. K. Steinvock through the courtesy of Mr. Russell W. Bowes and his associates of Todd Shipyards Combustion Equipment Division.

Being less encumbered by military restrictions, the Todd generator has been used in most of the projects upon which this preliminary report is based, and fairly complete photographic records of the work have been made by the authors and by others.

The Hochberg-LaMer generator was used experimentally, with gratifying results, to suppress an outbreak of canker-worms in a 10-acre wooded picnic area at Hempstead Lake State Park, and to suppress blackflies about the Lake Placid Club. No photographs were permitted during the course of these experiments.

The Todd generator first employed (Plate I, 2) was one of the portable screening smoke generators, originally produced in large numbers for use on landing craft and ashore, that had been slightly modified to operate at lower than screening smoke temperatures. This model has been progressively developed by Todd engineers (Plate II, 13, 17, 18, 23) in the light of their growing field experience.

BLACKFLY CONTROL EXPERIMENTS.—The Todd generator *TIFA* was used in exploratory blackfly control experiments at the town of Webb municipal golf course at Thendara and Old Forge (Plate I, 3 & 4). With the machine mounted on a light truck, the 60-odd acre golf course, together with included and surrounding wooded borders, was fogged lightly for a nonresidual kill of blackflies. About 10 acres at the most intensely blackfly-plagued corner were fogged more heavily for a study of residual effect. A 5 per cent solution of DDT in No. 2 fuel oil was used at an average rate of about 0.2 pounds and 2.0 pounds of DDT, respectively, per acre. The interior of the club-house was fogged heavily, with the result that houseflies, biting houseflies, blackflies and punkies were still being swept up from below the windows of the locker room and the office two weeks later.

The Todd generator, was used also in exploratory blackfly control experiments at the village of Blue Mountain Lake. With the machine mounted on a boat propelled by an outboard motor, this lake shore village (Plate I, 5) and neighboring summer resort hotel properties like the "Hedges" (Plate I, 6) were fogged from the water. A 5-per cent solution of DDT in kerosene was used at an average rate of about 0.2 pounds of DDT per acre. A cow exposed to the fog continued on pasture through sun and rain. Thirteen days later a lock of hair taken from this cow's back and placed in a large glass tube killed most of the blackflies caged with it in 3 hours, and gave a 100 per cent kill by next morning. Leaves and bark of a paper birch tree 75 feet from the lake shore, also 13 days after fogging, likewise killed all of the blackflies caged upon them over night.

PUNKIE CONTROL EXPERIMENTS (Plate I, 7 & 9). The Todd generator was used

EXPLANATION FOR PLATE II

FIGS. 13, 14, 15 & 16.—Fly control experiments at Staten Island, refuse-disposal landfill.

FIG. 17.—Cockroach control experiment at the Central Park Zoo, New York City.

FIG. 18.—Clothes moth control experiments in a large wool storage warehouse.

FIGS. 19, 20 & 21.—Mosquito control experiments at Jones Beach, L. I.

FIG. 22.—Tick and tick borne Rocky Mountain spotted fever control experiments.

FIGS. 23 & 24.—Fog generator mounted on an amphibious military "weasel."

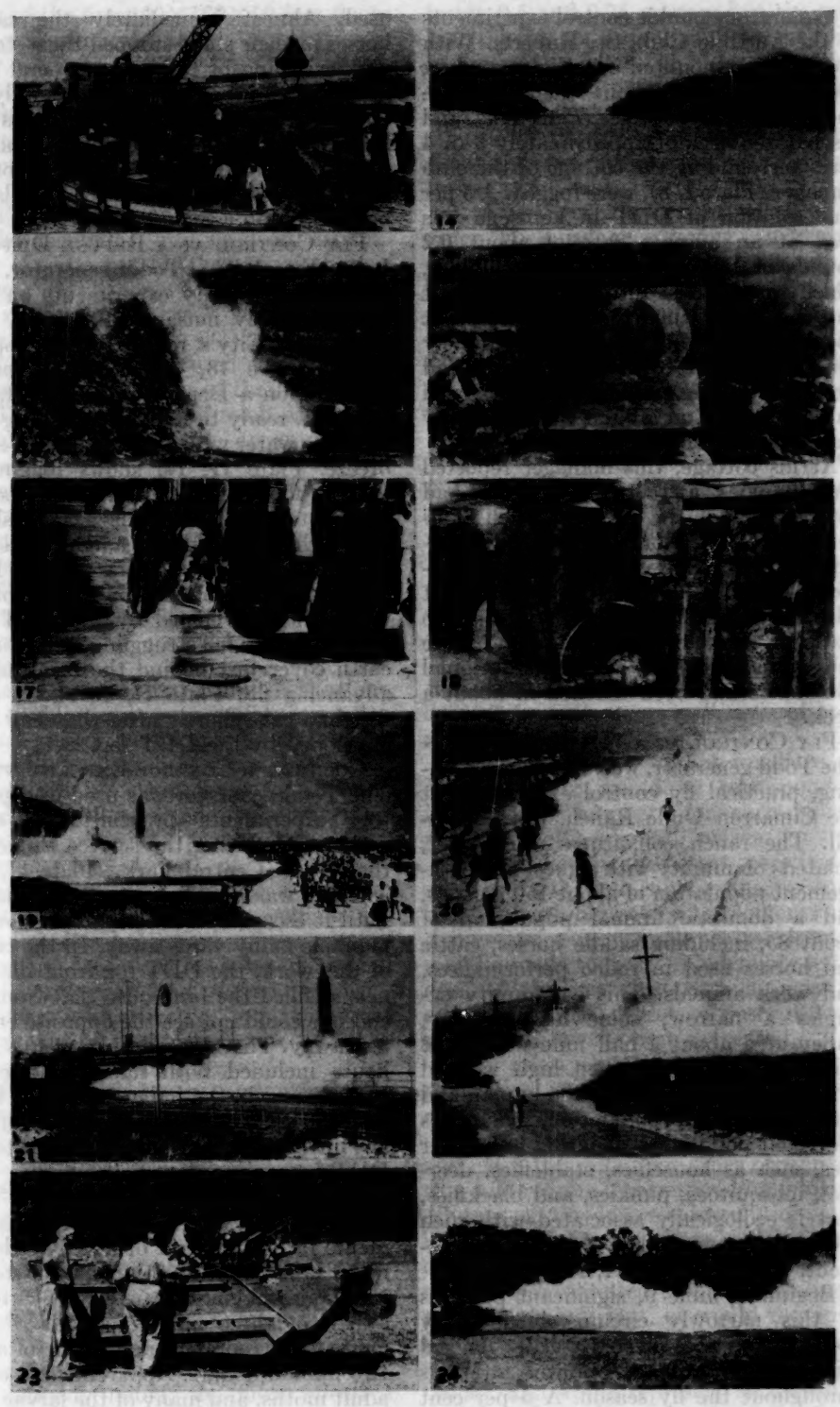

PLATE II

in exploratory punkie control experiments at the AuSable Club, St. Huberts. With the machine mounted on a light truck, a considerable area about the clubhouse and neighboring cottages (Plate I, 7), and a separated area of approximately 3 or 4 acres surrounding the cottage of the club manager (Plate I, 8), were fogged. A 5 per cent solution of DDT in kerosene was used at an average rate of about 0.2 pounds of DDT per acre. The punkies, which were almost intolerably abundant and aggressive when the work started at about 6.30 A.M., vanished immediately when enveloped by the fog. Dead and feebly struggling punkies were observed on porches and on ground cloths suitably placed before the operation.

At his cottage, this manager reported that punkies attracted by lights had entered through the screens in such numbers as to make work at his desk impossible at night. Subsequent to the experimental fogging, he reported no punkies at all for 3 days, after which they began to reappear, and became gradually more and more numerous until their original abundance had been reached in about a week.

FLY CONTROL AT A "DUDE RANCH."—The Todd generator, was used in a season-long, practical fly control experiment at the Cimarron Dude Ranch, near Peekskill. The ranch constitutes a compact, isolated community with a guest and management population of about 150 persons, and a domestic animal population of about 85, including saddle horses, cattle and horses used in rodeo performances, and work animals. This community occupies a narrow, somewhat swampy, valley area about a half mile wide by 2 miles long, lying between high wooded ridges, and in addition to the human and domestic animal population, comprises the usual population of biting and other flies, such as houseflies, stableflies, deerflies, mosquitoes, punkies, and blackflies, that is ecologically associated with such a community in such a physical environment. (Plate I, 9, 10, 11, 12)

Beginning June 9, significant portions of this narrowly circumscribed valley community were systematically fogged with DDT at appropriate intervals throughout the fly season. A 5 per cent solution of DDT in kerosene or No. 2 fuel oil, according to availability, was used. Almost immediately the saddle horses in their stalls stopped their stamping, switching of tails, and general restlessness, and began feeding quietly. A large portion of the valley area was also blanketed with the fog on each occasion. A remarkably thorough practical control of the flies was accomplished. Details will be reported in a separate paper.

FLY CONTROL AT A REFUSE DISPOSAL LAND FILL.—The Todd generator, was used in exploratory experiments on control of the fly nuisance associated with New York City's refuse disposal operations. Figure 13, shows the generator mounted on a Department of Sanitation tug boat, ready to fog the unloading area from the water with the aid of an on-shore breeze. Plate II, 14, shows fogging of heavily fly-infested refuse-bearing scows waiting to be unloaded. Plate II, 15, shows the machine mounted on a light truck fogging the heavily infested, 36-foot high, advancing front of the landfill. Swept upward when enveloped by the DDT fog, swarms of flies fell struggling feebly on the earth cover just behind the brink of the advancing fill. Plate II, 16 shows dead flies in a cage shortly after they had been enveloped by the DDT fog.

COCKROACH CONTROL EXPERIMENTS.—The Todd generator was used in exploratory experiments on control of cockroaches inhabiting the service tunnels of the Zoo in Central Park, (Plate II, 17). The fog was directed into each manhole until it escaped from the next uncovered manhole many yards away. In the course of this work, the DDT fog from the tunnels so filled the birdhouse that from one end one could not see the opposite end 75 feet away. The 150-odd birds in this birdhouse included both native and exotic species; and in the judgment of the keepers expressed 3 weeks later, none suffered any ill effects from this exposure to the DDT fog.

CLOTHES MOTH CONTROL.—The Todd generator, was used in exploratory experiments on the control of a heavy clothes moth infestation in a large wool-storage warehouse having a capacity of two and a half of three million pounds of high grade wool, representing a value of about two million dollars. Apparently all of the adult moths, and many of the larvae were killed by a single application of DDT at the rate of approximately a pound to

each of the five 100×160×10 foot floors. Time required was about 15 minutes per floor.

EXPLORATORY EXPERIMENTS (Plate II, 19, 20, 21, 22).—The generator was employed in exploratory experiments on the use of thermal aerosol DDT fogs for control of mosquitoes, sandflies, "greenhead" horseflies, and the like.

The generator was used in exploratory experiments on the use of thermal aerosol DDT fogs for control of the tick carrier of Rocky Mountain spotted fever.

The generator, was used in exploratory experiments on the use of thermal aerosol DDT fogs for control of adult salt marsh mosquitoes. Mounted on an amphibious military "weasel" (Plate II, 23, 24) the fog generator can be taken anywhere on the marsh so as always to release the fog down-wind toward any area that is to be treated. If a pond or stream is in its path, the "weasel" can dive in, swim across, and climb out on the other side without interrupting the operation of the generator.

Many persons, and many institutions, both public and commercial, have collaborated in some manner to make more complete the studies upon which this report is based. Due credit for this collaboration will be given in the reports on individual projects.

DISCUSSION.—In all of the projects mentioned in this report, a ground-operated thermal aerosol insecticide fog generator has been used. Both types of generator, however, have been adapted also for operation from the air.

But however operated, both the unique advantages of the thermal aerosol fog as a means of applying insecticides, and the conditions which govern, and in each special case establish limits within which its practical usefulness must lie, are concerned with particle size.

Mechanical sprays vary widely in particle size, depending upon the pressure and the type of nozzle employed, the droplets ranging from something like 40 or 50 microns to about 150 microns in diameter, and having an average diameter for the sprays usually employed probably in the neighborhood of 100 microns.

As already noted, the most effective oil-fog "screening smoke" is composed of droplets the diameter of which lies between 0.5 and 0.75 micron; but the military oil fog generator has been modified to produce a wide range of larger particle sizes up to, and overlapping that of the finer mechanical sprays.

Some of the factors which govern the significance of particle size may be illustrated as follows:

1. *Number of particles per square millimeter.* For airplane spraying, an insecticide in oil solution applied at the rate of 2 quarts per acre is considered by some operators to represent an economical balance between pay-load and coverage, with the concentration employed adjusted to give the desired quantity of the insecticide per unit area.

At 2 quarts per acre:

(a) With droplets *100 microns (0.004 inch) in diameter*, there would be approximately *1 droplet for each square millimeter* of horizontal surface.

(b) With droplets *10 microns in diameter*, there would be approximately *1000 droplets for each square millimeter* of horizontal surface.

(c) With droplets *1 micron in diameter*, there would be approximately *1,000,000 droplets for each square millimeter* of horizontal surface.

(d) With droplets of intermediate diameters, there would be corresponding intermediate numbers for each square millimeter of horizontal surface.

With exceptionally potent insecticides, such as DDT and gammexane, in combination with high efficiency solvents and carriers, even very small aerosol droplets may be made to carry an adequate lethal dose of the insecticide, which may be adjusted to the degree of susceptibility established for the pest concerned.

The relatively huge droplets of a mechanical spray, by contrast, would each carry many times the adequate lethal dose and be correspondingly wasteful and extra-hazardous for other organisms, or would require a correspondingly higher dilution of the insecticide solution; and in the latter case, if considered in terms of lethal projectiles per unit volume of space or per unit area, would be relatively sparse and inefficient, or would require a volume of the insecticide solution which would be prohibitive for application from the air, and would represent an excessive cost for the solvents and carriers employed, and a much greater danger of

injury to foliage from their excessive use.

2. *Limiting Factors.* The thermal aerosol fog is not driven mechanically to any considerable distance from the nozzle of the generator. The long range effectiveness of the thermal aerosol insecticide fog which is one of its unique advantages, therefore, depends upon its transportation by the wind.

The relatively huge droplets of the mechanical spray fall in response to gravity very quickly to the ground, or upon objects encountered on the way. Such sprays are not effectively carried far by winds. For really effective use of mechanical sprays, therefore, it is usually necessary to bring the nozzle of the spray outfit in some manner near the object to be sprayed.

According to Gibbs, under ordinary atmospheric conditions the particles or droplets or a disperse system such as a spray or an aerosol fog will fall in response to gravity at the following rates:

Diameter of Droplet	*Rate of Fall per Second*
100 microns (1/250 inch)	300.00 millimeters (11.81 inches)
10 microns (1/2500 inch)	3.00 millimeters (0.118 inch)
1 micron 1/25000 inch)	0.03 millimeters (0.00118 inch)

Borne by a steady wind blowing horizontally at 4 miles per hour, (or 5.8 feet per second), droplets of the size indicated released at an elevation of 5 feet would be carried the following distances before reaching the ground:

Diameter of Droplet	*Distance Carried*	
100 microns	29.78	feet
10 microns	2978	feet (more than half a mile)
1 micron	297800	feet (more than 50 miles)

At its best, the wind borne insecticide aerosol fog may be regarded as a continuing barrage, or as flying clouds of lethal projectiles, so closely spaced as to leave no voids through which the insect object of attack can escape being hit.

In practical operation, of course, the aerodynamics involved in the effective use of insecticide aerosol fogs are far less simple than these tables might seem to indicate.

Instead of following a linear, horizontal path, winds are complex systems of turbulent eddy currents moving in a general horizontal direction; and their turbulence may be increased by obstacles in their path. In consequence, the individual droplets of a wind borne aerosol fog may be propelled in all directions in the course of the general drift; and may approach an insect or other object encountered in their flight either directly or obliquely, and with varying velocities from below, from the sides, or from the rear, as well as from above or from in front.

Furthermore, probability of contact with, and deposit upon an object in its path is also a function of the particle size or mass and the velocity of a droplet, and of the form and dimensions of the object; the smaller the droplet, the more likely it will be to follow the stream-line of the air currents flowing past, without impinging upon its target.

In general, it begins to appear that, out of doors, the best results may be expected from the use of aerosol fogs the droplets of which, according to conditions in each case, may range from about 10 microns to about 50 microns or more in diameter.

For example, the ground-operated thermal aerosol insecticide fog generator may often use a particle size in the lower range with advantage. The air-borne generator, however, must release its insecticide fog from several to many feet from the ground. For forest pest control, this may be at a height of 100 feet or more. Any insecticide application from the air must reach the surface in uniform strips to permit the operator to cover the area dependably, strip by strip. In forest pest, or orchard pest control, therefore, a coarse particle size is required to give the droplets sufficient weight and rate of fall; and in many cases there may be a question whether a mechanical spray is not to be preferred, since even this is difficult to apply with requisite precision if any considerable wind is blowing.

When a plane can fly only a few feet above the ground, as over a marsh or over a cultivated field, an aerosol fog of appropriate particle size may be definitely superior to a mechanical spray.

In many cases the down-wind drift of the aerosol fog may be made to contribute materially to precision and economy in applying an insecticide. In some cases, however, uneven topography, or obstacles such as buildings, dense masses of vegetation and the like, may so deflect the re-

sulting air currents as to leave dead spots untouched by the drifting insecticide fog.

Many details remain still to be worked out with reference to the most effective balance between particle size, wind velocity, and other factors, for insecticide aerosol fogs used out of doors. Indoors, as in warehouses and the like, a much smaller particle size appears to be preferable.

This report is a by product of an exploratory study of the thermal aerosol insecticide fog generator in several independent pest control investigations.

A more detailed report on particle size is in course of preparation.—1-28-46.

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Control of the American Dog Tick, a Vector of Rocky Mountain Spotted Fever: Preliminary Tests

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In recent years, tick borne Rocky Mountain spotted fever has become increasingly a matter of public and official concern in parts of southeastern New York. This disease was first reported in the State of New York as two cases in 1912 and one case in 1913. No other case was subsequently reported until 1924. Since 1924, however, the disease has increased progressively until by the end of 1944 there had been a total of 86 cases and 16 deaths, with 17 cases and 4 deaths in 1944 alone. This represents a general average mortality rate of nearly one death in each five cases, and of nearly one death in each four cases in 1944.

Largely concentrated in one township, though gradually extending its recorded range, all but four of these 86 cases have been reported from a single Long Island county, where the American dog-tick, *Dermacentor variabilis* (Say), has long been extremely abundant. This county, likely the the other minor endemic areas, lies in an important residential and recreational area tributary to metropolitan New York.

In consequence, fear of this tick borne disease has begun to inhibit full public use of the recreational facilities provided in our magnificent system of parkways, parks, picnic grounds, and bathing beaches, not only in the area of greatest tick abundance and most intense concentration of spotted fever cases, but in other areas as well, where ticks are not uncommonly encountered.

In consequence, also, officials of the New York City Department of Health, of the State Department of Health, and particularly those of the Long Island State Park Commission and of the County Mosquito Extermination Commissions (the latter baffled by the prospective demand for control of the tick carrier over large areas), have expressed concern about this progressively increasing health hazard.

The investigation of control measures appropriate for use against the tick carrier of Rocky Mountain spotted fever is one of the earlier problems which have come to the entomologists of the newly constituted State Science Service, whose cooperation on this tick control problem was requested by officers of the Long Island State Park Commission, a subdivision of the State Conservation Department.

AN EMERGENCY PROBLEM.—The urgency of the situation appeared to demand the earliest possible arrival at even a partial solution of the problem. Lack of practical control measures has already

[1] *Acknowledgments.* The authors personally, as well as the State Science Service of the University of the State of New York are deeply indebted for their helpful cooperation to Dr. Robert Moses, Mr. Arthur E. Howland, Mr. Henry Reppa, and Frank W. Dickinson, all of the Long Island State Park Commission. They are indebted likewise to Mr. C. T. Williamson, Suffolk County Mosquito Extermination Commission, as well as to the Commissioners and to Perry B. Duryea, Commissioner of Conservation, New York State Conservation Department for their very helpful interest.

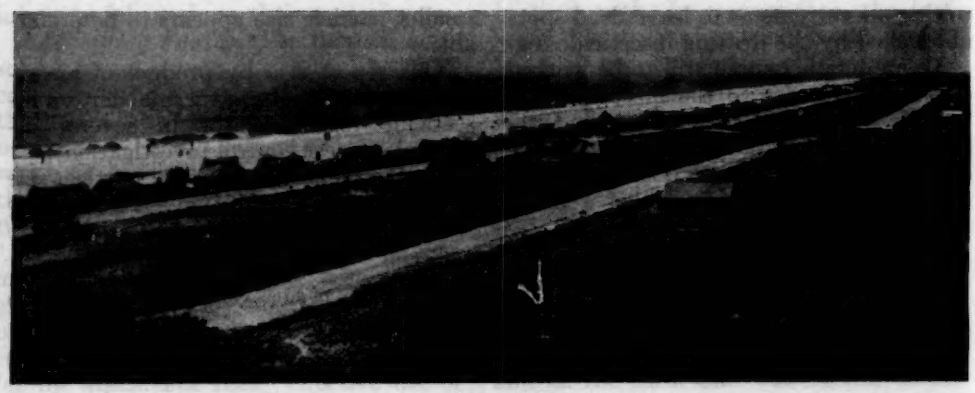

FIG. 1.—Ocean beach camping area at one New York State Park. Capacity 400 tents. Population sometimes considerably more than 1000 campers, with many additional picnickers and one day visitors. Berry pickers and hikers in nearby dune and heath areas must be constantly on guard to remove accumulated ticks promptly from their clothing and persons.

taken a too heavy toll in human suffering and human life. Further delay must correspondingly increase that toll.

Further delay at this stage to re-study more than a few locally significant details of the life history, habits and ecologic interactions of the tick carrier, therefore, appeared unwarranted; particularly so, since similar studies had already been carried so far under approximately comparable conditions by Hunter, Parker, Cooley, Bishopp, and others. For these reasons, this none the less essential phase of the problem was set aside for later investigation and further refinement when the immediate urgency of the situation had in some degree been met and opportunity might permit. This meant a substantial reorientation of conventional academic research technique, to approximate something more on the order of industrial research procedure.

Accordingly, it was decided to begin work by assembling experimental quantities of previously employed acaricides, together with such other readily available products as might seem to have promise of acaricide value. Then, at a field station where ticks could be easily collected in sufficient quantities, (1) rapidly to carry out a series of screening tests to eliminate products of less immediate promise; (2) with the more promising materials to make preliminary, small scale field tests; (3) with materials finally selected, to work out minimum effective quantities per unit area; and (4) based upon data so obtained to work out plans for large scale field tests next season, extending the recent pioneer work of Bishopp, Smith, Gouck, and others.

The ticks appeared to be adequately abundant on the Montauk peninsula, whereupon the Long Island State Park Commission made available a very conveniently located and equipped cottage at Hither Hills State Park for use as laboratory headquarters; and both the Long Island State Park Commission and the Suffolk County Mosquito Extermination Commission provided very helpful equipment, personal services, and materials needed to advance the work more rapidly.[1]

COLLECTION OF TICKS FOR TESTS.—Other animal hosts of the ticks, like most humans, prefer to follow lines of least resistance; and, instead of breaking new trails, are prone to follow beaten paths. From their normal ecological interactions, therefore, ticks should be far more abundant along frequently used animal trails; an hypothesis that was amply borne out by our experience.

Between 1500 and 2000 ticks were easily collected for use in the desired screening and other tests, by the simple process of walking along animal trails in the heath vegetation, and stopping now and then to pick accumulated ticks from one's clothing, principally from one's trouser legs.

Along one such trail, the junior author collected 60 ticks in less than a minute. At another spot, after having picked off all of the accumulated ticks, a single step gave 20 more ticks attached to one trouser leg.

MATERIALS TESTED.—Materials tested for acaricide properties included: DDT; gammexane[1] (10 per cent gamma isomer); rotenone (derris extract); nicotine alkaloid; pyrethrins; *Lethane 384 Special; Halowax 1000* plus *1014*;[2] and several special compounds which were provided in confidence by various manufacturers and research laboratories for preliminary testing in connection with this work.

SCREENING TESTS.—To find the acaricide or combination of acaricides which might appear to have most promise for early large scale experimental use under field conditions, a series of rapid screening tests were made.

It was decided to explore first, the acaricide performance of the tested materials when in oil solution, since under the requirement of large scale application this appeared to be better suited for use both as sprays applied from airplanes, and as aerosol fogs applied from thermal aerosol fog generators operated from airplanes or from the ground.

It had been planned to use a No. 2 fuel oil as the most economical available carrier solvent; but owing to a delay in delivery, an available supply of No. 4 diesel (fuel) oil was used instead in the earlier series of tests. The results were verified in later tests when a supply of No. 2 fuel oil became available.

For these screening tests solutions of various arbitrarily chosen concentrations were made up, and into each of these solutions the allotted number of ticks were dipped, then dried on absorbent paper, and each lot placed in a stoppered glass tube containing a strip of absorbent paper to which the ticks might cling.

Under the conditions of the experiment DDT, gammexane and the pyrethrins, rotenone and nicotine appeared to be most promising; lethane and halowax, as used, appeared to show less promise, and these accordingly, together with other unnamed materials tested, were set aside for further study at some later time.

PRELIMINARY TESTS IN THE FIELD.—The list of acaricide materials to be tested further was now narrowed down to DDT alone, gammexane alone, pyrethrins alone, DDT plus pyrethrins, gammexane plus pyrethrins, DDT plus nicotine, and gammexane plus nicotine.

[1] Hexachlorocyclohexane, sometimes called benzene hexachloride or "666."
[2] Achlorinated naphthalene mixture.

A relatively barren area was chosen for the tests. This was sparsely covered with isolated, individual tufts of grass such as the ticks appeared to prefer along the animal trails while awaiting the passing of a host animal. Here individual tufts of grass were colonized with ticks using from 10 to 20 ticks per test in different series; and then, with a special atomizer operated by compressed air, sprayed with the solution to be tested, after which the sprayed ticks were recovered and placed for observation, each lot in a separate cylindrical cage made of 24-mesh galvanized screen wire cloth.

In the first series of preliminary field tests, ticks that dropped to the ground when sprayed were sometimes difficult to find. In subsequent tests, the loose soil was consolidated, and the sprayed ticks made easier to recover by pouring plaster of paris mixed with water to a cream-like consistency about the base of each experimental tuft of grass to form a disc with a radius of about 8 inches.

Two series of these tests were made in which the percentage concentrations differed as follows: In the first of the two series, 0.25 per cent was arbitrarily chosen as the concentration for both pyrethrum and nicotine, and 1.0 per cent for both DDT and gammexane, whether used singly or in combination formulas.

DDT and the available sample of gammexane (10 per cent gamma isomer) both appeared under conditions of the experiment to be acaricides of promise, as did also the oil solutions of pyrethrins and of nicotine; while both DDT and gammexane in combination with pyrethrins or with nicotine alkaloid as employed in these tests were correspondingly more effective.

Because of an accident, rotenone did not receive an adequate test. This will be corrected in the 1946 series of experiments.

TESTS OF QUANTITY PER UNIT AREA.—While DDT and gammexane, either singly or in combination, appeared to have much promise as acaricides for use under field conditions, final tests of measured quantities per unit area were limited to DDT, which should be abundantly available next summer, while the availability of gammexane was then not yet assured.

In large scale regional spraying or fogging operations, such as apparently will

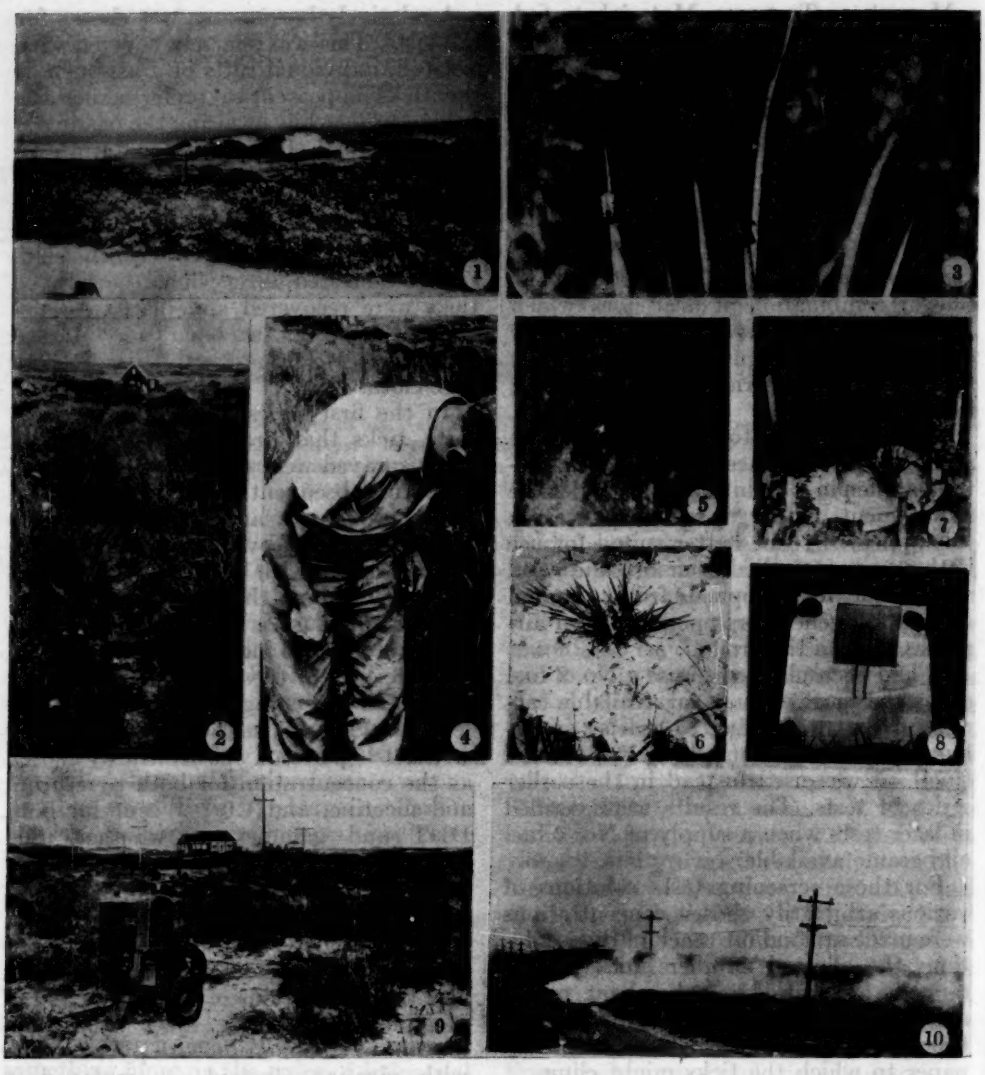

FIG. 2.—1.—Tick infested dune area. 2.—Tick-infested heath in background. Ticks were especially abundant along animal trail in foreground. Water supply pump house in middle distance. 3.—Ticks on vegetation. 4.—Ticks on legs of trousers, accumulated in two steps along trail in Fig. 2. Here berry pickers, hikers and others must be constantly on guard to remove ticks from their clothing and persons. 5.—An attached tick, not discovered until 24 hours after working in a tick infested area. 6.—Isolated tuft of grass colonized with ticks for acaricide tests. The plaster of paris disc consolidates loose earth, and facilitates recovery of treated ticks. 7.—Wire cage with removable top, embedded at bottom in plaster disc. Used in special tests. 8.—Inclined, 4 inch square support of screen wire netting, mounted on hairpin-shaped standard of heavy wire thrust into the ground through a paper towel in the center of a measured square yard area. 9.—Gasoline motor driven air compressor used to operate lacquer sprayer in experimental studies of minimum effective quantity per unit area. 10.—Preliminary test of ground operated thermal aerosol fog generator for application of acaricide formulas.

be necessary for any effective tick control in this Rocky Mountain spotted fever area, it may be important to find the smallest effective quantities of the acaricide per unit area in order to minimize any possible harm to wild life, or any possible disturbance of the general biologic balance.

In a series of tests to determine the minimum effective quantities per unit area, DDT plus pyrethrins was used in three concentrations which were pro-

gressively scaled down from those used in previous tests, and each test was made in triplicate.

In this series of tests, the ticks were placed on an inclined rectangle of screen wire cloth mounted on a hairpin-shaped support of heavy wire which could be thrust into the ground. These screen-wire rectangles were used once only, and then thrown away.

Carefully measured quantities of the acaricide solutions, sufficient for 1 square yard at the rate of 2 quarts per acre were diluted sufficiently with additional No. 2 fuel oil to permit accurate spraying over a measured, square yard area.

The measured solution was placed in a 4 dram vial in the glass jar of an automobile lacquer sprayer, the feed tube placed in the vial, and the liquid atomized by compressed air from a gasoline driven motor-compressor set to start and stop automatically between 100 and 120 pounds pressure.

Appreciably less than the set amount was actually applied to the experimental square yard in each case because a very considerable amount of the mist produced would invariably drift beyond the limits of the measured area. The resulting data, therefore, are well on the conservative side.

Here, as in the preceding tests, the sprayed ticks were recovered and each lot was placed in a separate cylindrical cage of 24-mesh, galvanized wire-cloth for subsequent observation.

As shown in table 1, a No. 2 fuel oil solution containing as little as 0.250 per cent DDT plus 0.0625 per cent pyrethrins used at a rate equivalent to 2 quarts per acre, (but diluted with additional fuel oil as indicated above, to become equivalent to 8 quarts per acre of 0.0625 per cent

Table 1.—Tests for minimum effective quantities per unit area. Materials tested were dissolved in No. 2 fuel oil.

Dosage Expressed in Terms of:				Condition[2] of Ticks After					
				18 hours			5 days		
Pounds per acre	Per cent[1] concentration computed at 2 qts. per acre	Per Cent[1] Concentration as Used. Equivalent to 8 Qts. per Acre	Replicates	A	F	D	A	F	D
DDT+Pyrethrum	DDT+Pyrethrum	DDT+Pyrethrum							
0.020+0.0050	0.5 +0.125	0.125 +0.0312	1	0	0	10	0	0	10
			2	0	0	10	0	0	10
			3	0	0	10	0	0	10
0.010+0.0025	0.25 +0.0625	0.0625 +0.0156	1	0	2	7	0	0	9
			2	0	0	9	0	0	9
			3	0	1	8	1	0	8
0.005+0.00125	0.125+0.0315	0.03125+0.0079	1	1	1	8	1	0	9
			2	2	1	7	1	2	7
			3	0	4	6	0	0	10
Check	(No. 2 fuel oil only)		1	9	0	1	8	0	2
			2	10	0	0	8	1	1
			3	10	0	0	7	2	1
Check	(No treatment)		1	10	0	0	8	1	1
			2	10	0	0	9	0	1
			3	10	0	0	10	0	0

[1] Of DDT, grams per 100 cc.
[2] A—Active; F—Feeble; D—Dead.
The ticks were exposed on inclined 4-inch squares of screen wire netting carried on hairpin-shaped supports of heavy wire thrust into the ground in the middle of a marked area one yard square.
Two quarts per acre appears to be accepted by some operators as representing maximum pay load compatible with minimum effective volume of solution when used in airplane spray.
Two quarts per acre equal approximately 6¾ drops per square yard.
In the table the insecticides used are expressed: A. As equivalent "per acre" quantities; B. As per cent dilution computed at 2 quarts per acre; and C. As per cent dilution in the larger volume (equivalent to 8 quarts per acre) actually found necessary to permit uniform and reasonably accurate distribution of the desired experimental quantities over the measured square yard with experimental equipment used.
More concentrated stock solutions were reduced to desired percentages by volumetric dilution.
The spray was applied with a Kellogg automobile lacquer sprayer operated by compressed air at 100 to 120 pounds pressure.

DDT plus 0.0156 per cent pyrethrins) appeared under the conditions of the experiment to be sufficient to assure practical control. Even half of these percentages used at the same rate per acre still gave a surprisingly complete kill.

DISCUSSION.—Although having begun when the season was already well advanced, a general orientation of the problem has nevertheless been made, apparently sufficient to justify tentative plans for some rather large scale control experiments in 1946, using DDT alone, and in combination with pyrethrins if available, and possibly also with nicotine and with rotenone. If the at least equally effective gammexane should be available for use in 1946, that also will be included in the program of large scale experiments.

Details of these tentative plans await additional orientation studies early in 1946, which will precede and help to indicate the dates most likely to be favorable for large scale, practical control operations.

As previously indicated, present plans contemplate the application of selected acaricide formulas by spraying from the air and as thermal aerosol fogs both from airborne and from ground operated generators.

While substantial progress appears already to have been made, a great amount of work remains to be done, not only on new acaricides, acaricide formulas, and methods of application, but particularly on the general ecologic interactions of Rocky Mountain spotted fever and its tick carrier in our New York endemic areas.

The minimum effective quantities indicated in the past season's work were based upon fully exposed ticks. In large scale field tests another year, considerably larger quantities will be included in the series to assure compensation for any shielding effect of the heath vegetation, with final recommendations held to the minimum that may be justified by results.

The waiting ticks appear usually to be quite fully exposed; so much so that a light application should easily reach them; but a very considerable part of the tick population will still be attached to host animals or in the egg stage, and thus beyond reach of a broadcast application of an acaricide spray or fog.

It seems likely therefore that any effective application may have to be repeated at intervals during the season, and probably one or more succeeding seasons to effect adequate control.

Applications, as of DDT, for residual effect do not appear to be called for, or likely to be justified by results; and the persistence of the causative agent (*Rickettsia*) of Rocky Mountain spotted fever through the egg stage to make carriers of several successive generations of ticks, seems to make long continued use even of the most effective tick control measures necessary if the disease is to be thoroughly rooted out.—1-28-46.

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TENTH ANNUAL PEST CONTROL OPERATORS CONFERENCE

The tenth annual pest control operators conference was held at Purdue University January 27 to February 1, 1946. The total attendance exceeded 260; 109 of these were new to the conference while 10 had attended all the previous meetings. The program maintained its usual high standard, with innovations making it of greater value in many respects.

DDT Thermal Aerosol Fogs to Control Clothes Moths in a Wool Storage Warehouse

D. L. COLLINS and R. D. GLASGOW, *University of the State of New York, Albany*[1]

A large manufacturer of high grade woolen fabrics, with a huge but uneven turnover of raw wool brought together from many sources, has experienced in corresponding magnitude the clothes moth control problem that is inevitably associated with woolen industries.

The huge stocks of raw wool required by this company are received and stored until required in a brick and reinforced concrete warehouse which measures approximately 100 by 160 feet on the ground, with five stories of which the first measures 13 feet, and the remaining four 10 feet from floor to ceiling. The capacity of this warehouse, depending upon the degree of compression in bags or bales, is from two and a half to three million pounds of wool, which would represent a value of approximately $2,000,000.

Wool arriving in bags and bales, particularly that from foreign sources, is likely to be heavily infested with one or more of the common clothes moth species. Especially in summer (the warehouse is not heated in winter), a general and economically significant population of clothes moths is likely to be built up throughout the warehouse unless vigorous control measures are consistently enforced.

The nature of the products manufactured requires expensive, high grade, long staple wool. Any considerable cutting of this long staple by clothes moth larvae working in the outer layers of the bales, or throughout the more loosely consolidated bags of wool may become economically significant, since any resulting short fiber wool must be separated out prior to carding and spinning, and must be sold for use in other channels at a loss.

The labor cost would make moving and spraying the bags and bales at regular intervals prohibitively expensive; and cyanide fumigation has not appeared to give results commensurate with its cost and inconvenience.

In 1945 the problem was referred to the entomologists of the New York State Science Service. Since this was an industrial problem of considerable magnitude, and of universal interest to woolen industries throughout the state and elsewhere, a cooperative research project was suggested. This was based upon the hypothesis that an appropriate insecticide aerosol fog produced by a ground operated thermal aerosol generator might provide effectual control at low cost, and with a minimum of inconvenience in comparison with older control procedures. Accordingly, plans for a preliminary experimental demonstration test were presented to, and generously accepted by, a manufacturer of such equipment.

CONDITIONS GOVERNING THE EXPERIMENTS.—In the warehouse there is an enclosed stair-well near the middle on the side nearest the factory. This gave access to each floor during and after the fogging operation. An elevator in a closed shaft near the center of the building allowed easy transportation of the machine from floor to floor. An overhead enclosed passageway connects the third floor of the warehouse with the factory.

The infestation appeared to be general, but rather heavier on the fourth and fifth floors. One or more lighted moth traps, each equipped with a collecting receptacle and a motor driven fan had been installed on each floor in an earlier control experiment. These traps were used to provide one type of check on the results of the aerosol fog experiments.

PREPARATIONS.—On October 4th, all the moth traps were thoroughly cleaned out, and were then kept running continuously until the day before the experiment. They ran for a similar period following the fogging. From October 4 to October 15,

[1] *Acknowledgments.* The authors personally, and the New York State Science Service are indebted

1. To officers of the collaborating woolen mill, for making their storage warehouse available for the investigation, for providing supplementary research materials and equipment, and for making collection notes and records essential to the study.

2. To Mr. Russell W. Bowes and Mr. Frank K. Steinrock of Todd Shipyards Combustion Equipment Division, for providing a portion of the research materials and for the use of a thermal aerosol fog generator (The *Todd Insecticide Fog Applicator* or *TIFA*) which was brought to the site of the investigation and operated by Mr. Norman McDonald and Mr. Joseph Muscara, under the personal supervision of Mr. Steinrock.

3. To Socony-Vacuum Oil Company for experimental materials provided through the courtesy of Mr. Warren Beman and Mr. A. C. Pabst.

4. To E. I. duPont deNemours & Company for experimental materials provided through the courtesy of Dr. H. F. Dietz.

the day before the fogging operation, more than 5000 moths, most of them *Tineola bisselliella* Hummel, had been trapped.

As a further check on moth abundance, timed hand-collections were made on October 15 by placing a wide mouth vial over the moths observed as they alighted on or crawled over a bag or bale. In this manner as many as 25 to 30 moths could be captured in 5 minutes on the fifth floor, and from 2 to 8 moths in 5 minutes on the floors below.

On October 15 the temperature was 58° F. at the time when check moth collections were being made; yet the moths, of which hundreds were observed resting on the bales of wool, were very active when disturbed, and were occasionaly seen in spontaneous flight. One pair was found mating.

Approximately 200 moths and numerous larvae were collected, and distributed among several cylindrical cages made of 24-mesh wire cloth, which were to be placed for exposure to the aerosol fog at significant points on the various floors, some near the floor and some near the ceiling; some in the open, and some well sheltered behind bales and bags of wool. A loose tuft of wool was placed in each cage to provide more congenial resting places for the insects.

FORMULAS AND PROCEDURES.—Since the season was already late it was decided to limit the tests at this time to DDT alone and DDT plus pyrethrins, in combination with different solvents, carriers, and dispersants.

It was planned to use a different for mula on each floor, and to begin on the top floor in order to avoid passing through heavily fog-charged spaces as the tests progressed.

One feature that was given special thought was the possibility that the dispersion of an oil fog within a confined space might create a fire hazard, either during or following the operation, or might even create an explosion hazard. These questions merit, and later will receive special study. On this occasion, however, the problem was met by using a water emulsion of the oil solution, or by the addition of non-inflammable carbon tetrachloride.

Formulas used on the different floors were:

Fifth floor. Approximately 10 per cent DDT in a solvent composed of a high boiling aromatic petroleum hydrocarbon,[1] 1 part, and carbon tetrachloride, 3 parts.

Fourth floor. The same as on the fifth floor, but with approximately 0.5 per cent pyrethrins added.

Third floor. DDT 12.5 per cent in an emulsion made up from equal parts water and an emulsifiable concentrate containing 25 per cent DDT.[2]

Second floor. Approximately 8 per cent DDT in a solvent comprising equal parts of carbon tetrachloride and a high boiling, paraffin series, petroleum hydrocarbon.[3]

First floor. The same as on the fifth floor.

The thermal aerosol generator (Fig. 1) placed on a hand truck was easily pushed about and taken from floor to floor on the elevator.

An earlier plan for moving the machine about to assure thoroughly fogging all

FIG. 1.—Thermal aerosol fog generator on 5th floor of wool storage warehouse.

parts of a floor was rapidly simplified when it was found that from one position near the elevator, the fog readily searched out and penetrated to all of the corners and crevices.

A very thorough fogging of each floor was accomplished in about 15 minutes, using quantities of the corresponding formulas equivalent to about one pound of DDT per floor. The entire operation was completed in about 2 hours.

The fogs from the 12.5 per cent DDT,[2] and the carbon tetrachloride-hydrocarbon[3]

[1] Socony-Vacuum "*PD 544 D.*"
[2] Dupont *Deenol.*
[3] Socony-Vacuum *Prorex B.*

formulas were both irritating to the eyes, nose, and throat, that from the latter somewhat less than the former. The fogs from the other formulas were relatively non-irritating.

The temperature during the fogging operation was 60° F.

The cages containing moths, some of which also contained nearly full grown larvae, were placed in positions on and behind bales or bags on October 16, immediately before the fogging operation.

FIG. 2.—Coated glass slide for recording deposit of fog droplets, and cage containing clothes moth adults and larvae, in position for exposure to thermal aerosol fog.

The distribution of the cages and the mortality or survival data are recorded in table 1.

A zinc stearate-coated glass slide was placed face up beside each cage to provide an index to the quantity of deposit in different sections of each floor (Fig. 2).

A further study of performance of the fogs was made by placing coated slides back to back in pairs in representative locations, so as to face up and down, in and out, toward and away from the machine, and the like, and photomicrographs of the deposit on these slides were made. Analysis of these photomicrographs is reserved for a later report.

RESULTS.—The fogging operations were completed about 4:30 P.M. on October 16. When the warehouse was revisited about 10:30 A.M. on October 17, the air of unopened floors was hazy with still persistent fog. The doors of the first and fifth floors had been opened for work, but the odor of the fog was still noticeable.

Each floor was carefully inspected. Dead moths were scattered about by hundreds. At one spot near a window where the floor had been swept clean on the fifteenth, there were 40 or 50 moths per square foot. Not a living moth could be found except at a few places on the floor near doors or windows where there had been some air leakage; here a few moths were able to flutter their wings feebly. Very few could crawl feebly with the erratic, uncoordinated movements characteristic of DDT poisoning. Thirty such feebly struggling moths were captured and caged. The following day all were dead.

Of the 25 untreated, or "check," moths that had been caged on the fifteenth, only 8 were dead by 5:00 P.M. on the eighteenth.

In fogging the first floor on the sixteenth, the hand truck with the machine stood outside, directing the fog blast

Table 1.—Condition of caged clothes moths 24 hours after exposure to a DDT thermal aerosol fog.

FLOOR	CAGE NO.	LOCATION	NO. OF MOTHS	MOTHS DEAD	MOTHS LIVING BUT STRONGLY AFFECTED	MOTHS UNAFFECTED
Fifth	5a	top of bale	25	25	0	0
	5b	behind bale	25	25	0	0
Fourth	4a	top of bale	28	25	3	0
	4b	behind bale	20	20	0	0
Third	3a	top of bale	25	25	0	0
	3b	behind bale	25	24	1	0
Second	2a	top of bale	20	19	1	0
	Check	outside of building	28	3[1]	0	25

[1] At least one of these moths was already dead when examined immediately before fogging.

through an open door. During this operation many moths flew out from the fog filled room. Eleven of these were captured out of doors and caged. On the seventeenth only one remained alive. This surviving moth was still alive on the eighteenth, having apparently escaped a lethal dose of the DDT.

On October 18, several live moths were observed in the warehouse, but their fresh, unrubbed appearance indicated that they had emerged subsequent to the fogging operation. To check the possibility of residual DDT injury to these newly emerged moths, 14 were captured and caged. The following day, 10 were dead, and 4 were still alive and active.

During the morning of the seventeenth, all slides and all exposed caged moths and moth larvae were collected and examined. The condition of moths is shown in table 1.

The following cages also contained full-grown or nearly full-grown larvae: *Cage 5a*, five larvae; *Cage 5b*, five larvae; *Cage 3b*, five larvae. The larvae were not visibly affected the first day after the fogging, but on the second day, (October 18), at 4:45 P.M., of the five larvae in Cage 5a, all were dead; in Cage 5b, four were dead, one was alive but very feeble; in Cage 3b, two of the five were living and not visibly affected. The other three were dead.

On October 30 a few recently dead, and a few feebly moving, moribund larvae were observed on the floor near bags and bales of wool. Apparently these larvae, emerging from within the wool to spin their cocoons on the outer surface of the burlap enclosure, had encountered lethal quantities of residual DDT.

COMPARISON OF TRAP CATCHES.—The traps were placed in operation again the second day after the fogging (October 18) and were examined on the twenty-sixth and the thirtieth, after a period equivalent to the period during which counts were made before the fogging, namely, about 11 days. The data obtained from the traps for equivalent periods before and after the fogging are given in table 2.

The average temperatures on the several floors during the period covered by these records ranged from 58° to 63.5° before the fogging and from 58° to 62.5° after the fogging. That a difference in temperature did not cause the sharp decline in the numbers of adult moths present was indicated by the similar temperatures before and after the treatment and by the observations of moths in active flight immediately before fogging.

Table 2.—Numbers of clothes moths taken in traps.

Location of Trap	Trap No.	Before Fogging (Oct. 4–15)	After Fogging (Oct. 18–30)
5th Floor	54D	1500	0
	55C	400	2
	57A	400	0
	58D	2000	0
4th Floor	44A	400	0
	47A	10	1
	47D	40	0
3rd Floor	33C	137	0
	34A	52	0
2nd Floor		400	0
1st Floor		250	0

DISCUSSION.—From the experimental study here reported, it appears that an insecticide aerosol fog may have special advantages indoors for some types of insect pest control work. More searching than mechanical sprays of coarser particle size, the aerosol fog apparently is less subject to loss of concentration through leakage than is the case in fumigation with a gaseous insecticide.

Since all the DDT-bearing thermal aerosol fogs used in these experiments killed practically 100 per cent of the adult moths in a heavy warehouse infestation, nothing is left upon which to base comparisons, nor an appraisal of the value of added pyrethrins.

Not only were the adult moths virtually all killed by the DDT aerosol fog, but even the little DDT that was used seems to have left residual deposits which killed at least some of the subsequently emerging moths, and some of the surviving larvae.

Moths and larvae exposed in cages were killed.

The possibility that thermal aerosol fogs may provide a much more economical pest control procedure for use in warehouses than any of the older methods of warehouse pest control, seems very promising indeed.

The use of DDT aerosols in food stor-

age warehouses, however, would be quite inadvisable.

Plans for continuing the studies another season contemplate further work with DDT, as well as work with other promising insecticide materials and with other solvents, carriers, and dispersants appropriate for use indoors.

Apparently smallness of particle size is an important factor in governing the persistence and searching properties of a thermal aerosol fog when used indoors. Continued studies of this factor are included in the agenda for another season's work.—1-9-46.

Japanese Beetle Attractants with Special Reference to Caproic Acid and Phenyl Ethyl Butyrate

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Geraniol and eugenol, in combination, are well known as an effective attractant for Japanese beetles. Langford *et al.* (1943) reporting on studies with Japanese beetle baits showed that there are many chemicals attractive to Japanese beetles. Attractive materials were found among the alcohols, acids, oils, esters, and aldehydes as well as other chemicals. Results were also reported which showed that mixtures or combinations of many of these attractants were far more effective for attracting beetles than any component when used alone. Often the attractive value of a mixture would exceed the sum of the attractive values of the constituents.

During the war several modified bait formulas were offered to conserve geraniol and eugenol. Fleming & Chisolm (1944) suggested anethole as a substitute for geraniol. Muma, *et al.* (1945) suggested caproic acid diluted with oil as a partial replacement for either or both materials. However, substitute formulas were not offered that would entirely replace both these materials or give greatly increased attractiveness above that obtained from the standard formula of 9 parts of geraniol and 1 part of eugenol.

Expanded studies with mixtures this past summer gave results which appeared to have both these qualities, and in addition point to new horizons for developments in attractants for Japanese beetles. With 100 selected mixtures, 40 combinations were found with distinct attractiveness. Ten combinations ranged from two to three times as effective as the geraniol-eugenol standard. Sixteen ranged from as good to almost twice as good, and 14 ranged from three-fourths as effective to equal effectiveness (Table 1).

Two chemicals, phenyl ethyl butyrate and caproic acid were exceedingly promising as ingredients for baits. When used together, or in combination with anethole and valeric acid, or phenyl iso valerate, they made baits that compared favorably with geraniol and eugenol as used in the standard. A simple combination of caproic acid, 8 parts, and phenyl ethyl butyrate, 2 parts, gave results indicating attractiveness was within the range of the standard. Tests involving 25 replications caught 24 per cent more beetles.

Caproic acid seems to have unusual qualities for improving many bait mixtures. When used as a partial replacement and in combination with anethole, eugenol or geraniol, attractive values soar. In some combinations the efficiency is more than doubled. Phenyl ethyl butyrate is likewise a most useful chemical for improving bait efficiency in combinations containing geraniol and eugenol, or combinations in which these materials have been partially replaced by either anethole or caproic acid. Its addition in certain instances resulted in doubled efficiency.

From the standpoint of simplicity and economy, caproic acid, 8 parts, and phenyl ethyl butyrate and eugenol (50–50), 2 parts, was one of the most efficient and practical combinations tested. It can be recommended for field use and as a replacement for field formulas now in use. This formula in 29 replications caught over twice (2.8) as many beetles as the geraniol and eugenol standard.

Ethyl caproate, phenyl iso butyrate, phenyl iso valerate, and iso valeric acid

Table 1.—Results from mixed attractants for improved Japanese beetle baits.

Mixture	No. of Replications	No. of Beetles Caught	Per Cent Relative Efficiency
Excellent Mixtures. Baits More than Twice as Attractive as Standard			
Caproic acid, 8 parts; eugenol and phenyl ethyl butyrate (50-50), 2 parts	29	30,210	283.6
Caproic acid, 8 parts; phenyl iso valerate and eugenol (50-50), 2 parts	2	6,105	264.1
Caproic acid, 9 parts; eugenol and phenyl ethyl butyrate (50-50), 1 part	2	6,951	300.7
Caproic acid, anethole and iso valeric acid (equal parts), 8 parts; phenyl ethyl butyrate and eugenol (50-50), 2 parts	2	3,219	284.8
Caproic acid and anethole (50-50), 8 parts; geraniol, eugenol, phenyl ethyl butyrate (equal parts), 2 parts	2	2,333	206.4
Caproic acid and anethole (50-50), 9 parts; eugenol and phenyl ethyl butyrate (50-50), 1 part	2	6,417	278.7
Caproic acid and geraniol (50-50), 8 parts; eugenol and phenyl ethyl butyrate (50-50), 2 parts	2	5,491	231.9
Caproic acid and anethole (50-50), 9 parts: eugenol, 1 part	2	5,664	246.4
Phenyl ethyl butyrate, 8 parts; eugenol and geraniol (50-50), 2 parts	2	15,711	222.3
Phenyl iso valerate, 8 parts; eugenol and geraniol (50-50), 2 parts	2	15,384	379.1
Good Mixtures. Baits from as Attractive to Twice as Attractive as Standard			
Anethole, 9 parts; eugenol and phenyl ethyl butyrate (50-50), 1 part	2	2,234	113.5
Anethole, 8 parts; geraniol, eugenol and phenyl ethyl butyrate (equal parts), 2 parts	2	3,362	114.3
Caproic acid, 8 parts; phenyl ethyl butyrate, 2 parts	25	12,233	124.3
Caproic acid and anethole (50-50), 8 parts; Eugenol, 2 parts	2	6,903	132.5
Anethole, iso valeric acid, caproic acid (equal parts), 8 parts; phenyl ethyl butyrate, 2 parts	2	2,292	120.1
Anethole, iso valeric acid, caproic acid (equal parts), 8 parts; citronella and phenyl ethyl butyrate (50-50), 2 parts	2	2,610	113.0
Caproic acid, 8 parts; geraniol, 2 parts	0	3,920	102.7
Caproic acid, 8 parts; eugenol and geraniol (50-50), 2 parts	2	5,766	173.3
Caproic acid and anethole (50-50), 9 parts; geraniol, 1 part	2	4,189	181.9
Caproic acid, 8 parts; geraniol, eugenol, phenyl ethyl butyrate (equal parts), 2 parts	2	4,371	177.5
Eugenol, 9 parts; phenyl ethyl butyrate, 1 part	2	3,340	144.5
Geraniol, eugenol, phenyl ethyl butyrate (equal parts)	2	3,211	195.0
Geraniol, 8 parts; eugenol and phenyl ethyl butyrate (50-50), 2 parts	2	3,411	144.1
Phenyl ethyl butyrate and eugenol (9-1) (mixture diluted 50% with mineral oil)	10	46,920	109.3
Phenyl ethyl butyrate and caproic acid (50-50) (mixture diluted 50% with mineral oil)	10	45,295	105.5
Phenyl ethyl butyrate and eugenol (50-50)	2	11,240	122.5
Mixtures Less Attractive, but Approaching Standard in Attractiveness			
Anethole, 9 parts; eugenol, 1 part	25	55,990	76.0
Anethole, 9 parts; eugenol, 1 part	25	54,742	76.5
Anethole, 9 parts; eugenol, 1 part	2	6,073	75.9
Anethole, 8 parts; eugenol and phenyl ethyl butyrate (50-50), 2 parts	2	1,650	83.8
Anethole, 8 parts; eugenol and phenyl iso valerate (50-50), 2 parts	2	1,722	87.5
Caproic acid and geraniol, (9-1) diluted 50% with mineral oil	10	17,502	79.0
Caproic acid and mineral oil (50-50), 9 parts; geraniol and eugenol (50-50), 1 part	50	125,982	92.6
Caproic acid and mineral oil (50-50), 8 parts; phenyl ethyl butyrate, 2 parts	25	56,904	77.2
Caproic acid, 9 parts; phenyl iso valerate and phenyl ethyl butyrate (50-50), 1 part	2	2,321	77.8
Caproic acid and anethole (50-50), 9 parts; phenyl ethyl butyrate, 1 part	2	2,180	94.7
Ethyl caproate, 9 parts; geraniol and eugenol (50-50), 1 part	2	6,736	90.5
Phenyl ethyl butyrate and standard (9-1) (mixture diluted 50% with mineral oil)	10	35,856	83.5
Iso valeric acid 8 parts; standard, 2 parts	2	8,211	79.1
Citronellol, 9 parts; eugenol, 1 part	5	29,498	77.4

are other chemicals which in limited tests gave outstanding and attractive baits when used in various combinations with caproic acid, eugenol, geraniol and phenyl ethyl butyrate. Formulas with these chemicals are, however, more complicated and expensive. But the trends in efficiency of some are such that they should be further studied. A most promising mixture was phenyl iso valerate, 8 parts, and eugenol and geraniol in equal mixtures, 2 parts. This formula caught over three (3.7) times as many beetles as the standard.

When compared with geraniol and eugenol the chemicals used in these studies are highly volatile, and the more efficient mixtures which contain high percentages of them may evaporate from two to three times as fast as the geraniol and eugenol standard. This brings in the question of possible influence of the evaporation rate on improved efficiency. There is ample evidence to indicate this is a factor with certain mixtures. Langford *et al.* (1943) commented on results they obtained. Workers using geraniol and eugenol to attract Japanese beetles have long known the catch can be greatly increased by increasing evaporating surface. But in addition to the influence of evaporation rate, evidence indicates two other factors are important; namely, the chemicals in the mixture and the ratio in which they are combined. Evidence on the ratio of chemicals in the mixtures are displayed in work with anethole and caproic acid. A mixture consisting of anethole, 9 parts, and caproic acid, 1 part, was only 12.3 per cent as efficient as the standard bait. By changing the combination to one of caproic acid 50 parts and anethole 50 parts, efficiency was increased to 58.3 per cent.

METHODS AND VALUES.—Results on all bait mixtures reported in these studies were obtained under field conditions and with traps and equipment other than bait, identical. The traps were arranged in batteries spaced at intervals of approximately 10 feet, and with a minimum of one standard for each four, but more often each two traps under test. Test mixtures were replicated two or more times. Traps under test were rotated every day.

The efficiency of all baits was computed against geraniol 9 parts and eugenol 1 part, which is termed the standard bait in these studies. The oil, where used in bait mixtures was in all instances white mineral oil (Saybolt viscosity 125–135).

In considering the values of the different bait formulas it should be pointed out that expressed efficiencies are only relative and in relationship to the particular chemicals used in these experiments. In most instances the chemicals used were of a technical grade and replacements would vary to some extent depending on sources and lot. Long experience has shown the comparative efficiency of standard baits prepared from different lots of geraniol always varies appreciably. Even individual traps with standard bait prepared with identical materials, same source, same lot, may vary as much as 20 per cent both above and below the average.

The results reported in these experiments do, however, represent trends and indicate the relative values for different combinations for practical application.—1-9-46.

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DR. GRESSITT RETURNS TO CHINA

Dr. J. Linsley Gressitt has recently been separated from the Navy where he served as Entomologist in U. S. Naval Reserve Unit No. 2 and also as a member of the staff of the Commander, U. S. Fifth Fleet.

Dr. Gressitt is returning to the Natural History Survey and the Biology Department of Lingnan University, Canton, China, to resume the work on which he was engaged at the outbreak of the war. He may be addressed in care of Lingnan Natural History Survey and Museum, Lingnan University, Canton, China.

Rate of Development of Milky Disease in Japanese Beetle Populations[1]

J. A. Adams and E. H. Wheeler, *Poughkeepsie and Geneva, N. Y.*

The use of milky disease bacteria for the control of the Japanese beetle, *Popillia japonica* Newman, has become a well established practice. The spore-dust method of colonizing *Bacillus popilliae* Dutky, devised by the U. S. Department of Agriculture in the late 1930's has been applied, through federal and state cooperation, over most of the infested territory in the eastern United States (White & Dutky 1942). Possibilities of applying the method to other scarabaeoid insects are being explored, and public confidence is reflected in the fact that spore dust is now being produced commercially.

Interest in materials which can be applied on soil to kill Japanese beetle larvae has been stimulated by the discovery that as little as 25 pounds of actual DDT (dichloro-diphenyl-trichloroethane) will practically free an acre of ground from Japanese beetle grubs in one season (Hadley & Fleming 1944). When contrasted with chemicals for soil treatment the milky disease has the advantages that it is entirely harmless, that its benefits naturally spread outside the treated plot, and that it need not be repeated (White 1940; White & Dutky 1940; Wheeler & Adams 1945). It has, however, the disadvantage inherent in its cumulative action—it is relatively slow to bring about control.

In the earlier years when spore dust was still scarce and was distributed only by government agents it was usually applied as sparingly as seemed consistent with the aim of getting the disease organism widely introduced. With greater supplies now available there is a tendency not only to establish colony plots closer together but also to use more spore dust on a unit area in order to bring about satisfactory control more quickly. The main purpose of this paper is to present the results of testing heavier spore dust dosages to shorten the interval between application and control.

The data may also be useful in indicating the rate of milky disease development at soil temperatures encountered in the north part of the present continuous distribution of the insect. Dutky (1940) found that the interval between injection of larvae with infective doses of spores of *Bacillus popilliae* and the appearance of macroscopic symptoms was 6 days at 30° C, 11 days at 22° C and 14 days at 17° C. The threshold of development was found to be near 16° C. It can be assumed that the spread of the host insect into cooler regions is accompanied by a trend toward slower action of the milky disease organism.

The main Japanese beetle infestation in New York in 1945 was confined to New York City, Long Island and a few counties in the Hudson River Valley—an area of about 3500 square miles, or 7 per cent of the state. That the insect will eventually infest a much larger area is indicated by the persistence and growth of numerous isolated colonies as much as 100 miles farther north. The State Department of Agriculture and Markets reports the application in the 5-year period 1940 through 1944, of about 6550 pounds of spore dust on about 3850 acres of plots. Although insect parasites, especially *Tiphia vernalis* Rohwer, are being colonized in these areas, the state is relying mainly upon milky disease to avert prolonged economic losses.

Spore Dosage in Field Colonization.—The number of spores of *Bacillus popilliae* which must be present in the soil surrounding Japanese beetle larvae to bring about a substantial rate of infection is known to be remarkably high. Dutky (1941) recommended that for laboratory feeding tests the larvae be placed in soil containing about two million spores to the gram of soil. Beard (1944) worked out a linear relationship between spore content of soil and the rate of infec-

[1] Eastern Branch program 1945. Approved by the Director of the N. Y. State Agricultural Experiment Station for publication as Journal Paper No. 659, January 2, 1946.

tion of third instars. A spore concentration of about two million spores to the gram of soil produced the infection of only 50 per cent of the larvae. For field tests Dutky recommended that 200 million spores be applied to the square foot, and this was the unit for soil inoculation adopted in the standard spore dust methods of the U. S. Department of Agriculture. About 200 million spores, contained in 2 grams of spore dust, are dropped at a "spot" on the soil surface. On the square foot on which the spot is centered at least some of the larvae become exposed to infective concentrations. At the usual rate of application by government agents in New York the spots are set at 10-foot intervals. In effect, then, 1 square foot in each area 10 feet square may be considered as inoculated, and the remaining 99 square feet are left to benefit from development and spread of the organism. At this rate 2 pounds of spore dust, when released as 453.6 separate 2-gram quantities, are distributed over an area of 45,360 square feet or 1.04 acre. Table 1 shows a convenient method of relating various

Table 1.—Dosages of milky disease spore dust as usually applied by the "spot" method.

Dosage	Area per Spot	Number for an Area 10 Feet Square			For 45,360 Sq. Ft. or 1.04 Acre
		Spots	Grams	Spores in Millions	
Standard	10′×10′	1	2	200	2 lbs.
	10′× 5′	2	4	400	4 lbs.
	5′× 5′	4	8	800	8 lbs.
Commercial	5′× 5′	4 (tsps.)	10	1000	10 lbs.

dosages for the 10-foot-square area, expressed in grams, and the corresponding dosages for 1.04 acre expressed in pounds. The instructions accompanying commercial spore dust usually call for spots at 5-foot intervals with a dosage of 10 pounds to the acre; the spots, which are to be applied with a spoon, evidently have to average more than 2 grams.

PREVIOUS RESULTS FROM VARIOUS SPORE DOSAGES.—Owing to the subterranean habits of the host, accurate evaluation of milky disease as a factor in mortality is not easy. In the fall of 1943 and the spring and early summer of 1944, a very limited survey was made of soil populations on, and near, milky disease plots, chiefly on golf courses on Long Island and in the Hudson River Valley. The plots had been treated with spore dust at the rate of two pounds to the acre in 1940 or 1941. In the square-foot areas dug directly on the plots the populations were generally lower and the percentages of larvae found diseased were about twice as high as in the square-foot areas dug one-eighth mile away from the plots (Wheeler & Adams 1945). Evidence from these and more recent diggings gives the impression that in New York, following the spot application of milky disease spore dust at the rate of 2 pounds to the acre, on scattered half-acre plots with fairly dense infestations, a reduction of population to the point where only a few beetles emerge from the square foot, requires an interval of 3 to 4 years. In New York City in 1943, and in the adjacent counties in 1944 and 1945, the damage by adult Japanese beetles to foliage was generally much less than in several previous years. While milky disease was certainly a factor in this change, in so far as it affected the larvae on properties actually treated, its value over the whole area remains unascertained. *Tiphia* parasites and drought conditions in the summer of 1943 and 1944 are also recognized as factors of locally varying importance. It seems likely, however, that there were important depopulating factors at work which were not readily observable from soil diggings.

Results of heavier spore dosages are stated only in very general terms. Previous to the adoption of standards for spore dosage, White & Dutky (1940) tried in the field, chiefly in New Jersey, spore concentrations from 25 million to 1500 million to the square foot and stated that "reduction of larval population to a point where no serious turf injury will occur can probably be obtained at any of these dosages, in one season or in several seasons, depending on the distance between the points of application." The data from a few cases of fairly heavy spore application in New York were too fragmentary to be conclusive. In view of the enormous multiplication of spores which must take place in the soil in the processes by which these bacteria bring about control, the raising of the original dose from 2 to no more than 10 or 12 pounds to the acre has not seemed to the authors to be likely to lead to satisfactory control in New York in one larval season. It was, therefore, decided to investigate higher

spore dosages under New York conditions.

FIELD PLOTS AND METHODS.—In the last week of April, 1944, two series of sod plots located on the outskirts of Poughkeepsie, New York, were treated according to the dosages shown on Table 2. Series H consists of five plots situated on the baseball field of the Hudson River State Hospital. Series G consists of five duplicate plots adjacent to the eleventh fairway of the golf course of the Dutchess

Table 2.—Heavy applications of milky disease spore dust on plots at the Dutchess County Country Club (G) and at the Hudson River State Hospital (H).

SERIES AND PLOT NO.	DOSAGE, SQ. FT.		CORRESPONDING DOSAGE FOR 1.04 ACRE
	Spore dust, in grams	Spores, in millions	
G-, H-10	0.1	10	10 lbs.
G-, H-100	1.0	100	100 lbs.
G-, H-500	5.0	500	500 lbs.
G-, H-1000	10.0	1000	1000 lbs.
G-, H-2000	20.0	2000	2000 lbs.

County Country Club. The site of the H series is nearly level, surrounded by woods on the north and west, and has a shallow loam soil laid on a very rocky subsoil. The site of the G series is more exposed, has a deeper sandy loam soil and supports a denser turf. The soil of the plots of the H series and of plot G-2000, which sloped south, tended to be warmer by a few degrees in the daytime than that of the other four plots, which sloped slightly northward. The vegetation consisted of various lawn grasses and common lawn weeds kept between two and four inches in height. The infestations in these areas had probably started in 1941 and were approaching the point of producing noticeable turf injury.

The spore dust used was standard material obtained from the Japanese Beetle Laboratory of the U. S. Department of Agriculture at Moorestown, N. J. It was suspended in water and applied broadcast with a sprinkling can. The heavier doses made a white coating on the grass and additional water was sprinkled on to wash the material into the turf. Sections of the turf for months afterwards showed a whitish streak in the dead grass and humus layers at the soil surface. The material was exposed to direct sunlight when applied.

The plots were made 10 by 10 feet square and were spaced more than 45 feet apart. The broadcast application made the areas uniform for immediate square-foot sampling; but it probably had a disadvantage in that, with the two lower dosages, the individual square foot received less spore dust than the 2-gram minimum used for the standard spot. The highest dosage, equivalent to about a ton of spore dust to the acre, was regarded as giving the soil about the same number of spores as might occur naturally after one milky-diseased larva had disintegrated in each square foot. It was assumed that larvae of various sizes dying of milky disease would average about two billion spores.

Diggings were made in the plots at intervals of about one to three weeks through the seasons of larval activity in 1944 and 1945. The unit of digging was one square foot, or one per cent of the plot area. The soil fauna of each square foot sample was examined by the senior author in the field. All living forms of the Japanese beetle were counted (Table 3, columns headed Lvg). Of these, any larvae showing macroscopic symptoms of milky disease were counted as milky (Mky). In doubtful cases a hemolymph smear was made for microscopic examination, and the grub was counted as milky if the smear showed well-formed spores of *Bacillus popilliae*. Pupae and adults were not examined for milky disease. Reasonable care was taken to protect the specimens from sunlight and from mandible injury, and to return them to the soil. A square foot, once dug, was levelled down, seeded and not dug again during that generation. Altogether, on the 10 plots, 347 square feet were dug and 8856 Japanese beetle forms recorded. Check diggings were made between 10 and 20 feet from the plots in various directions on areas resembling the plots in turf and soil. In all, 178 diggings were made in the two check areas and 5078 Japanese beetle forms recorded. Thus the data are based on nearly 14,000 living forms examined.

During digging operations thermometers were usually inserted into the soil of one or more of the plots and readings obtained near the surface and at the five-inch depth. Included in Table 3 are representative readings (more or less

averaged) from the five-inch depth. Temperatures in 1944 were unusually favorable to milky disease development. The U. S. Weather Bureau reported mean air temperature at Poughkeepsie for May, 1944 (the month following the spore application) as 67.7° F. or 8.1 degrees above the 42-year normal. The means for June, July, August, and September 1944 were 70°, 74.8°, 73.4° and 65.4° all one or two degrees above the normal. In March 1945, the mean air temperature was 11.7 degrees above the normal and the larvae came out of hibernation earlier than

Table 3.—Numbers of living Japanese beetle forms (Lvg.) and of larvae showing milky disease (Mky.) found in single square-foot diggings in plots treated, April 29, 1944, with various heavy applications of milky disease spore dust. Dutchess County Country Club, Poughkeepsie, N. Y.[1]

Date of Digging	Soil Tempr. F.[2]	On Check Area		On Plots; Single Square-Foot Counts									
				G-10		G-100		G-500		G-1000		G-2000	
		Lvg.	Mky.	Lvg.	Mky.	Lvg.	Mky.	Lvg.	Mky.	Lvg.	Mky.	Lvg.	Mky.
1944													
Apr.													
28	50	11[3]	0	36	0	16	0	21	0	19	0	41	0
May													
22	69	—	—	—	—	—	—	—	—	17	0	18	0
29	71	—	—	—	—	7	0	—	—	19	0	27	2
June													
6	73	—	—	—	—	14	0	20	0	34	0	16	0
20	73	—	—	—	—	—	—	—	—	—	—	16	0
26	77	—	—	—	—	7	0	11	0	18	0	12	1
28	74	—	—	14	0	14	0	10	0	21	0	13	2
July													
6	78	11[3]	0	8	0	11	0	6	1	10	0	19	1
July													
12	81	11[3]	0	—	—	—	—	—	—	5	0	3	1
22	75	—	—	31	0	15	0	87	0	17	0	29	1
Aug.													
3	75	—	—	110	0	14	0	65	0	38	0	54	0
12	75	—	—	—	—	—	—	—	—	—	—	30	1
17	78	—	—	63	1	50	0	57	0	32	0	42	0
23	75	46[3]	0	—	—	29	0	29	0	71	0	53	8
Sept.													
11	73	—	—	58	4	9	0	26	0	60	16	28	4
26	60	—	—	97	2	50	1	61	1	64	13	36	5
Oct.													
2	56	38[3]	0	77	1	42	0	38	1	58	5	36	9
13	59	71	0	88	0	34	0	46	5	68	1	54	1
1945													
Mar.													
30	58	—	—	70	0	25	0	70	0	61	1	38	0
Apr.													
12	59	64[3]	0	56	0	37	0	83	0	52	2	26	0
30	60	—	—	—	—	—	—	—	—	31	1	24	0
May													
14	58	38[3]	0	69	0	41	0	60	0	73	1	36	2
25	67	—	—	61	0	40	0	45	0	59	0	27	0
June													
5	59	26[3]	0	—	—	—	—	—	—	28	0	12	0
9	63	21[3]	0	40	0	53	0	21	0	—	—	—	—
12	74	29[3]	0	—	—	—	—	—	—	39	0	27	0
15	76	26[3]	0	54	0	23	0	39	5	—	—	—	—
19	73	28[3]	0	—	—	—	—	—	—	30	15	8	5
26–8	69	48	0	21	9	22	4	46	21	29	7	9	6
	71	18	0	25	8	14	3	41	9	33	3	10	6
	70	34	0	21	9	13	1	24	8	38	7	5	3
	74	36	0	27	0	12	2	35	6	19	17	14	13
	73	21	0	33	1	20	4	31	12	28	6	41	25

[1] Lines traversing the columns separate the larval seasons as defined in the text.
[2] Soil temperatures at the five-inch depth, close to the diggings.
[3] Average of two to five single square-foot counts.

Table 3.—(Continued)

Date of Digging	Soil Tempr. F.[2]	On Check Area		On Plots; Single Square-Foot Counts									
				G-10		G-100		G-500		G-1000		G-2000	
		Lvg.	Mky.	Lvg.	Mky.	Lvg.	Mky.	Lvg.	Mky.	Lvg.	Mky.	Lvg.	Mky.
July													
11	74	21[3]	0	25	2	8	2	8	2	14	2	23	4
16	75	37	0	—	—	—	—	—	—	30	0	—	—
23	75	33	0	—	—	—	—	11	1	—	—	—	—
30	77	5[3]	0	—	—	13	0	—	—	5	2	—	—
Aug.													
13	74	—	—	29	0	—	—	—	—	—	—	41	0
22	78	46[3]	0.2	41	2	48	4	48	3	41	6	17	1
Sept.													
3	74	39[3]	0	—	—	—	—	—	—	29	7	3	3
8	72	39[3]	0	27	1	31	0	17	5	—	—	—	—
22	66	43[3]	0	41	10	20	6	37	6	38	9	3	0
Oct.													
3	60	39[3]	0	42	6	28	7	15	5	39	13	3	0
20	58	35[3]	0	10	3	13	6	3	0	25	14	4	2

usual. The means for the months of April through October were, in order: 54.7°, 58°, 68°, 72°, 72.3°, 67.4° and 52°. (Christie 1944, 1945).

The snowy winter of 1944–5 seems to have caused practically no larval mortality. In the spring of 1945, birds and other predators were active on the check areas near the plots and in May the sod on a half-acre of fairway beside the plots of the G series was badly torn. During a prolonged rainy period in July 1945, the soil in and near plot G-500 was, for a time, water-soaked and gave off an odor of vegetable decay. Earthworms and some Japanese beetle larvae were found dead in the soil samples. The population of this plot was partially restored with the eggs laid after August 1.

RESULTS OF FIELD TESTS.—Since the diggings were made under continually varying conditions it is necessary to present the data in considerable detail. Single square-foot counts of living forms from the G series are shown in table 3. Parallel data from series H are not shown but the main differences between the data from the two sites are stated below. Detailed data on special diggings made just as beetle emergence was beginning in late June 1945 are given for both series in table 4. Following White (1940) the term season is used in a special sense. The beetle is regarded as having two seasons in each generation: a summer-fall season and a spring-early-summer season. Although the generations overlap in July the change of season in summer is here regarded as occurring when the living forms of the new generation begin to outnumber the remaining forms of the emerging generation.

The check diggings indicate that the 1944–45 generation was more numerous than the 1943–44 generation, on which the spore dust was applied. They also show that the milky disease organism must have been practically absent from the area before treatment and very slow to spread from the plots after treatment. Out of over 5000 forms dug in the check areas at the two sites in the year and one-half of observation only 5 larvae, all in the fourth or last larval season were found milky. From table 4 it can be seen that on the whole the population at the site of the H series was only about half that at the G series.

On plots G-10 and H-10, on which the spore dust applications were equivalent to 10 pounds to 1.04 acre, no milky-diseased larvae were found in the first season. On H-10 only two milky larvae were found in about 700 forms dug during the four seasons after treatment. On G-10, where populations were generally higher, the milky disease was found in the second season and may have killed about half that generation by the end of the third season. The percentage of surviving forms appearing milky late in June, 1945, on this plot, as shown in table 4, was about

Table 4.—Japanese beetle forms and incidence of milky disease in five one-square-foot samples dug in late June 1945 in each of two check areas and in each plot of two series treated with spore dust in April, 1944. Poughkeepsie, New York.

Forms	Check Area	Treated Plots				
		G-10	G-100	G-500	G-1000	G-2000
Larvae[1,2]	16	35	28	58	61	58
Prepupae	17	18	10	12	15	16
Pupae	122	65	43	104	70	5
Adults	2	9	0	13	1	0
Total Forms	157	127	81	187	147	79
Larvae milky	0	27	14	56	40	53
Per cent milky	0	21.3	17.3	30.0	27.2	67.0
		H-10	H-100	H-500	H-1000	H-2000
Larvae[1]	0	1	9	21	23	24
Prepupae	1	1	3[3]	2	1	4
Pupae	61	30	65	8	16	35
Adults	5	0	11	0	0	1
Total Forms	67	32	88	31	40	64
Larvae milky	0	1	9	21	23	16
Per cent milky	0	0.3	10.2	67.7	57.5	25.0

[1] Exclusive of larvae showing prepupal changes.
[2] Including one second instar; all others third instars.
[3] Hemolymph of one prepupa found with milky disease spores.

the same as the percentage obtained in a survey made in late June and early July 1944, on Long Island and in the Hudson Valley, on areas which had received spore dust at two pounds to the acre by the spot method in 1940 and 1941 (Wheeler & Adams 1945).

On plots G-100 and H-100 milky disease was not found until it appeared in young larvae in the second season. In the last three diggings in 1945 about one-third of the larvae were milky in G-100 and about one-seventh in H-100. On plots G-500 and H-500 milky disease appeared in the first season and gradually increased thereafter. In the last three diggings on H-500 in the fall of 1945 about one-third of the larvae were found milky.

On plots G-1000 and H-1000, which received spore dust at the rate equivalent to 1000 pounds to 1.04 acre, no milky disease was found until the second season but thereafter the incidence of disease was, on the whole, greater than with the lighter treatments. In the last three diggings in the fourth season about one-third of the larvae in these plots were found milky. Following such an incidence in the fall it can be expected that more than two-thirds of the larvae will have become diseased before emergence time in 1946.

On plot G-2000 which had received spore dust at the highest rate the disease made its most prompt appearance. On May 29, one month after treatment, among 27 larvae dug in one square foot, two were slightly milky. Smears showed the typical spores. On June 28, one square foot contained 4 active third instars, two of them milky, 1 prepupa, 7 pupae and 8 adults. Most of the population in this square foot had evidently escaped serious infection in the first season. From tables 3 and 4 it is evident that the incidence of infection was much higher one year later. The last four diggings made in this plot in September and October 1945 showed an average of only two non-milky larvae as compared with 39 on the checks. It is probable that emergence from this plot in 1946 will not exceed one beetle to the square foot. On the plot H-2000 the disease was not so effective, possibly because the population had not been as dense in 1944 as that on G-2000 (Table 4). The last three diggings on H-2000, made between September 13 and October 19, 1945, yielded 56 living forms of which 22, or about 40 per cent, were milky.

DISCUSSION.—On these plots it was necessary to use the broadcast method of application in order to obtain a uniform area for immediate square-foot sampling. Had the spore dust for these plots been applied by the spot method the lowest dosage would have been five 2-gram spots on the 10-foot square; the others in order would have received 50, 250, 500 and 1000 spots. At the two lowest dosages the spot method might have given better inoculation but for the highest dosage the difference between applying 10 spots on a square foot and uniform broadcasting does not seem likely to be important.

In view of the results described above, a generalization can be made which is applicable to conditions like those at Poughkeepsie, N. Y. Where standard spore dust is broadcast at the rate of one ton to the acre, on a growing larval population approaching the level of causing turf injury, a reduction of the population to the point where only a few beetles can emerge from the square foot requires at least five larval seasons or about two and one-half years. There is observational evidence that the same degree of population reduction can be achieved with only two to ten pounds of spore dust to the acre in about four years. It does not seem likely, therefore, that improvements in soil inoculation methods will take the

form of raising spore dosages far above those now in use. More accurate evaluation of the ordinary dosages, between two and ten pounds to the acre, under various conditions of climate and population are rather urgently needed. Since it is probable that part of the delay in the control after spore dust applications is due to slowness of the spores in entering the soil and reaching the larvae, closer investigation of factors in soil inoculation might lead to improved techniques of application.

It is well known that applications of milky disease spore dust, given enough time, can bring about a lasting reduction of Japanese beetle populations. It seems evident, however, that where larval populations are building up to destructive numbers milky disease alone should not be expected to prevent temporary high beetle populations and localized turf injury. On restricted areas where these conditions cannot be tolerated it seems wise to include chemical soil treatments.

SUMMARY.—Under climatic conditions at Poughkeepsie, N. Y. the currently used light dosages of standard milky disease spore dust containing *Bacillus popilliae* applied as soil inoculations to control the Japanese beetle, are known to be slow to act. Higher dosages, at five rates ranging from 10 to 2000 pounds to the acre, were applied in April on small field plots and the results observed by means of frequent soil diggings. A small percentage of diseased larvae was found in all the plots within 1 to 6 months after treatment; but a satisfactory degree of control was achieved only at the highest dosage after 18 months. The data indicate that, in southern New York, raising the dosage of spore dust applications from 2 pounds to the acre to 2000 pounds to the acre can reduce the time required to bring about satisfactory control from about 4 years to about 2 years. The results support the current practice of using standard spore dust at inoculative dosages wherever eventual and permanent reduction of Japanese beetle populations is sought. The results do not hold promise for the use of very heavy applications of spore dust to act as substitutes for chemical soil treatment on restricted areas where immediate control may be imperative.—1-9-46.

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An Evaluation of Various Sprays to Control Immature Squash Bugs

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One of the most annoying of pests in vegetable gardens, and frequently very destructive in commercial plantings, is the squash bug, *Anasa tristis* (Deg.). It is found throughout the United States wherever squash is grown, and has therefore been the subject of investigations conducted by many entomologists working under different climatic conditions and with numerous insecticides. Nevertheless, there has not yet been found a material which gives satisfactory kills of all stages of the pest when applied under field conditions by the average commercial grower. Statements which have appeared in recent literature do give considerable hope that this condition may soon be changed.

The extent to which the biology of the squash bug has been studied is indicated in the complete work on this subject by Beard (1940) in which 129 references to the literature are given. There are a number of other published articles dealing with control, both mechanical and chemical, but unfortunately none of them have so far solved the squash bug problem for large plantings. Quite likely this is due to a combination of two facts; first, that as yet no one has discovered a good ovicide which will give high kills of eggs and yet not be injurious to squash foliage, and second, that the easily used sprays or dusts which have been suggested have proven effective only against the younger nymphs. The latter has meant failure in field control unless sprays were applied frequently and regularly beginning when the first eggs hatched, and it has also meant failure where large numbers of overwintered adults have attacked fields while the plants in it were still small.

Fulton & Howard (1938) pointed out that the toxicity of rotenone to squash bugs was increased with the addition of mineral or vegetable oils. Later the same authors (1942) showed that it is desirable to use these oils in sulfonated form because of possible increase in toxicity to insect and certain decrease in toxicity to foliage. They found further that the addition of acetone to the sprays significantly increased their toxicities. Hoerner (1938) obtained good control from the use of a pyrethrum dust containing 0.4 per cent pyrethrins by making 13 applications at a cost of material and labor of $45.50 per acre. Under average conditions in New York such a cost would be too high and certainly few growers would make so many applications. Despite this fact, the New York recommendation for chemical control of squash bugs does include treatment with pyrethrum as do also the majority of recommendations followed in other areas, at least in so far as they have come to the attention of the writer.

In recent years two new materials have appeared to lend some hope of solution to the squash bug problem.[1] Swingle & Mayer (1944) found that 3 per cent DDT dust gave a 100-per cent kill of fourth instar nymphs as did also their pyrethrum standard. At the same time Harrison (1944) reported results of preliminary tests which indicated that a 10 per cent dust of the same material might also kill adults, but later Smith *et al.* (1945) obtained kills of only the young nymphs when treating summer squash with a 10 per cent aerosol.

Not often have insecticides been reported as effective against adult squash bugs but Dicke *et al.* (1945) found sabadilla dusts very toxic when used in concentrations of 25 and 30 per cent in preliminary trials. Apparently similar results were obtained in laboratory tests by Tate & Gates (1945) except for the fact that they found the toxicity of 5 and 10 per cent dusts slightly higher than did the other workers. As has always been the case, they found a gradation in toxicity of a given concentration to various stages, *i. e.*, the older the insect the more resistant to insecticide. Nevertheless, considerable toxicity to adults was noted, and it is to be hoped that more extensive tests will prove as encouraging.

In the investigations reported in this paper it has been the writer's purpose

[1] Since the preparation of this manuscript excellent kills of adult squash bugs with a chlorinated hydrocarbon, known as *1068*, have been reported by Kearns *et al.* (1945).

to evaluate various sprays against the eggs of the squash bug, and then, beginning with newly-hatched nymphs, to determine the toxicities of the sprays to older nymphs and possibly to adults. Thus each material was tested against successively more resistant of the active stages until no appreciable kills were obtained or until some other factor such as evident phytotoxicity or cost made further testing unnecessary.

REARING TECHNIQUE.—For several years cultures of squash bugs were maintained in the insectary at Cornell University in order that observations might be made on the biology of the species while at the same time furnishing adequate numbers of the various stages in the life history for numerous toxicological tests. Blue Hubbard squash plants were grown individually in 3-inch pots which could be set in regular greenhouse flats filled with soil to a depth just level with the tops of the pots. Usually five such pots were kept in each flat and each morning those plants which were badly wilted as a result of bug feeding were replaced with fresh plants. Frequency with which the plants had to be replaced depended upon the instar confined and the time of year. It was soon found that, bug-for-bug, the plant injury was less for early instars than for late ones and that for all, especially adults, feeding and other activities were slower in late fall and early winter than during other seasons. The cages used for rearing were approximately 24 inches long, 18 inches wide, and 12 inches high, thus conveniently fitting over greenhouse flats. They were covered with 16-mesh screen, fitted with grooved covers, and were kept in rows on greenhouse benches with 500-watt incandescent bulbs in 18-inch reflectors suspended above them. It was found that by leaving these lights burning about 6 inches above the cages on cloudy days, and at night during late fall and winter, the cultures could be maintained so as to supply all stages for toxicological tests except for a period of about 3 months in the fall.

While observing the activities of isolated pairs of adults it was found that of 6673 eggs laid in 481 masses only 75.06 per cent hatched, whereas of 520 water-sprayed eggs laid in 36 masses in what might be called "mass cultures," consisting of 40 to 50 pairs of adults, the hatch was 96.54 per cent. In the first case there was obviously less chance of copulation and in a number of instances eggs were laid by the female a considerable time after death of the male, so it was assumed that the low per cent hatch might have been due to incomplete fertilization. Thus, for all testing of materials as ovicides only egg masses from stock cultures containing fairly large numbers of mixed adults were used.

TESTING PROCEDURES.—Practically all the sprays included in the investigations were first tested as ovicides. Egg masses were taken from stock cultures of adults daily, placed in 10 cm petri dishes and passed through the endless-belt precision sprayer shown in figure 1. The pressure was usually adjusted to 15 pounds, the same as was also used for the spraying of active forms. After being passed

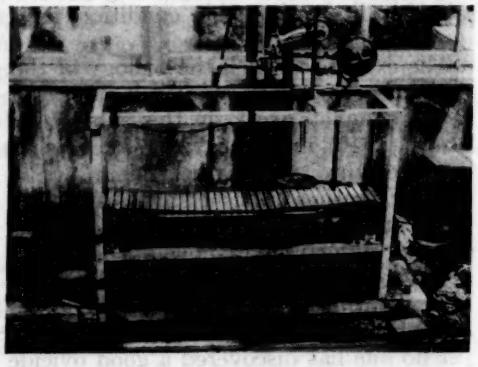

FIG. 1.—Endless-belt precision sprayer used in applying various sprays to all stages of the squash bug in the laboratory.

through the spray of either insecticide or water, the treated egg masses were transferred to clean petri dishes which were kept on a shaded greenhouse bench and opened daily for examination. Slightly moistened discs cut from paper towels were kept in the bottoms of the dishes to maintain a relatively high humidity in tests conducted in the winter.

For the testing of sprays against eggs the approximate number of replicates employed per dilution and the approximate number of individuals sprayed per replicate were 4 and 71 respectively; against young nymphs, 5 and 15; against old nymphs, 4 and 7; and against adults, 3 and 5.

In order to establish a basis for com-

parison of the toxicities of sprays to the active stages of squash bugs, and because it was already known that in general the younger the form the more susceptible it is, all of the sprays were first tested against newly-hatched first instar nymphs while their bodies were still green and their legs red. By means of a camel-hair brush they were placed in petri dishes in the bottoms of which were moistened discs of outing cloth. This material was used because it prevented the nymphs from being blown out of the dishes when they were uncovered and passed once through the sprayer. Immediately after being sprayed the nymphs were transferred to clean dishes containing freshly cut young squash leaves. In those cases in which observations were extended beyond 24 hours the old leaves were replaced with fresh ones daily. The criterion of death used was the inability of the individual to right itself within 30 seconds after being placed on its back as invariably those showing even active leg motion, but unable to right themselves, died without further feeding.

The materials which showed considerable toxicity to newly-hatched nymphs were also tested against nymphs at least 21 days old, and it was at this point that nearly all of the sprays proved ineffective at concentrations safe to foliage and sufficiently cheap to be used commercially. Only one material was used against adults, the testing procedure in this case being the same as for both young and old nymphs.

DISCUSSION OF RESULTS.—In table 1 are presented the data obtained in the tests of the sprays against eggs, young nymphs, old nymphs, and adults. To them the reader is referred for detailed comparisons of the toxicities of different concentrations although a few of the general findings are here summarized for convenience:

1. While a rather large number of insecticides or combinations of insecticides with fungicides were given trial, the vast majority of results were negative, indicating a marked degree of resistance of the squash bug to some of our most commonly used materials.

2. Of 26 sprays tested as possible ovicides none gave kills which could be interpreted as satisfactory for field use with the doubtful exception of a 20 per cent amine salt of dinitro-ortho-cyclohexylphenol. The only other which gave better than a 50 per cent kill was a light petroleum oil when used in concentrations known to be injurious to foliage.

3. The total number of sprays tested against newly-hatched nymphs was 21. With 12 of these it was possible to secure higher than 90 per cent kills but in most cases it was necessary to step up the concentrations to a point at which, for field use, the cost of 2 or 3 applications would cut considerably into the margin of profit generally realized in raising squash in New York. As was to be expected, materials containing pyrethrum showed very marked toxicities to the young nymphs. This was also true of rotenone sprays when used in rather costly concentrations.

4. Against nymphs at least 21 days old practically all of the 10 materials tested failed to give satisfactory results from the cost standpoint. Only one was given further testing against adults. In the failure of these materials to give kills of the older active forms at economical concentrations lies the key to many commercial failures. It explains our present necessity to treat when young nymphs first appear and then at rather short intervals under field conditions to keep on killing newly-hatched nymphs before they have attained their full measure of resistance.

5. It is very interesting to note that of three DDT sprays used only one made from an oil base proved effective against active stages. It was at first thought that such results might be due to the toxicity of the oil but oil alone gave poor kills unless used at much higher concentrations. One possible explanation lies in the thought that perhaps the oil base permitted better penetration of the DDT through the insect integument. It might be added here that in some field experiments the emulsible oil base containing 5 per cent DDT caused some injury to both tomato and squash plants but this difficulty, and the necessity for higher DDT content in sprays to kill all active stages, might possibly be met in commercial work by the use of an oil base containing a higher percentage of DDT which would in turn lower the amount

Table 1.—Results of laboratory tests of various sprays against immature squash bugs.

Spray Material	Dilution	Corrected per cent kills[1]		
		Eggs	Young nymphs	Old nymphs
Mannitan monolaurate[2] containing 1.1% pyrethrins	1:200	1.9		
	1:400	7.9		
Mannitan monolaurate[2] containing 2.0% pyrethrins	1:100			73.9
	1:200		100.0	59.6
	1:400		99.5	45.8
	1:800		100.0	26.9
	1:1600		88.0	17.9
	1:3200		43.8	0.0
	1:6400		28.0	
	1:12800		11.0	
5% dinitrocyclohexylamine salt of 2-4-dinitro-6 cyclohexylphenol+spreader[3]	3.4–100	4.4		
	1.7–100	10.0		
20% amine salt of dinitro-ortho-cyclohexylphenol[4]	16–100	74.7	97.4	0.0
	8–100		66.0	0.0
	4–100	62.3	21.7	
	2–100		0.0	
	1–100	55.3	0.0	
Light petroleum oil[5]	Undiluted	95.6		
	64:100	100.0	95.5	
	32:100		70.7	
	16:100	100.0	44.0	
	8:100	24.4	1.3	
	4:100	0.2		
	2:100	9.3		
	1:100	13.2	0.9	
Dioctylfumerate+benzyl phenyl-glycinonitrile (5:1 +spreader at 1:2500)[6]	1:200	0.0		
	1:400	4.4		
Pyrethrum extract containing 2.0 grams pyrethrins[7] per 100 cc.+emulsifier[8]	1:19	12.5	100.0	100.0[27]
	1:39		100.0	100.0
	1:79		100.0	79.1
	1:159		100.0	56.4
	1:318		98.8	0.0
	1:636		97.2	
	1:1272		84.7	
	1:2554		12.5	
	1:5108		14.9	
	1:10216		0.0	
Pyrethrum extract containing 2.0 grams pyrethrins per 100 cc.[9]+emulsifier[8]	1:50			73.9
	1:100	13.1		44.0
	1:200		100.0	17.9
	1:400	9.3	93.1	0.0
	1:800		62.7	0.0
	1:1600	2.8	9.2	
	1:3200		0.0	
Pyrethrum flowers containing 0.5% pyrethrins[10]	32–100			6.0
	16–100		100.0	13.0
	8–100		95.2	0.0
	4–100		62.5	4.2
	2–100		18.3	
	1–100		9.0	
	.5–100		0.0	
Pyrethrum flowers containing 0.92% pyrethrins	8.68–100	0.8		
	4.34–100	13.7		
	2.17–100	0.0		

Table 1.—*Continued*

SPRAY MATERIAL	DILUTION	CORRECTED PER CENT KILLS[1]		
		Eggs	Young nymphs	Old nymphs
1.4% pyrethrins+0.5% rotenone[11]	1:25			100.0
	1:50			59.8
	1:100	23.6		45.8
	1:200		100.0	0.0
	1:400	24.0	100.0	
	1:800		98.6	
	1:1600	0.0	78.8	
	1:3200		17.5	
	1:6400		3.1	
32.0% insecticidal oil containing 2.8% rotenone and 5.2% other derris resins[12]	1:100	9.9	91.9	
	1:200		84.7	
	1:400	25.6	50.1	
	1:800		17.7	
	1:1600	6.7	8.1	
3.0% rotenone, 6.0% other derris resins, 0.5% pyrethrins[13]	1:50			83.9
	1:100	10.4	97.7	75.9
	1:200		98.6	52.3
	1:400	8.7	83.4	0.0
	1:800		59.3	
	1:1600	5.0	51.2	
	1:3200		0.0	
Mannitan monolaurate containing 1.0% rotenone and 1.8–2.6% other derris extractives[14]	1:25			96.2
	1:50		97.0	59.8
	1:100	19.0	67.7	27.7
	1:200	20.1	46.1	0.0
	1:400	0.0	15.7	
	1:800		4.5	
93% yellow cuprous oxide[15]	3.0–100		3.3	
	1.5–100	0.0	4.3	
93% yellow cuprous oxide[15]+mannitan monolaurate containing 1.1% pyrethrins[2]	1.5–100+			
	1:200	8.3	87.5	
	1:400		85.9	
	1:800		46.3	
	1:1600		43.8	
	1:3200		19.9	
93% yellow cuprous oxide[15]+mannitan monolaurate containing 1.0% rotenone[14]	1.5–100+			
	1:100		100.0	
	1:200	8.8	89.8	
	1:400		58.8	
	1:800		0.9	
	1:1600		0.0	
Copper oxychloride sulphate[16]	12–100		3.7	
	6–100		0.2	
	3–100	7.4	0.5	
	1.5–100		0.0	
50% yam bean in pyrophyllite[17]	16–110	2.2	20.1	
	8–100	12.8	18.8	
Tartar emetic+sugar	8–16–100	3.5	33.5	
	4–8–100	8.8	23.8	
	2–4–100	0.0	4.1	
1.0% nicotine tetrahydroanacardate+0.25% emulsifier[18]	1:100	0.0		

Table 1.—*Continued*

Spray Material	Dilution	Corrected Per cent Kills[1]		
		Eggs	Young nymphs	Old nymphs
Nicotine sulfate[19]+laundry soap at 4–100	1:50			38.6
	1:100			0.0
	1:200	14.0	77.9	
	1:400	18.3	23.1	
	1:800		5.1	
	1:1600		0.0	
	1:3200		0.0	
Dichloroethyl ether+equal volume of stock emulsifier (1 g/100 cc.)[20]	1:50		3.7	
	1:100		0.0	
Chlorinated hydrocarbon[21]+0.5% bentonite+0.5% emulsifier[22]	2:100	17.1		
50% DDT+49.5% bancroft clay+0.5% emulsifier[22]	16–100		6.0	
	4–100	8.7	18.9	
	.5–100	2.8	12.8	
20% DDT+4.5% sticker+3% wetting agent[23]	8–100	0.8	0.0	
	2–100		0.0	
	.5–100		0.0	
5% DDT in oil base[24]+emulsifier[3] at 1:1000	17.54:100			85.1
	8.72:100			14.2
	4.36:100	26.0	100.0	6.7
	2.18:100		72.9	0.0
	1.09:100		26.7	
	0.55:100		4.1	
	0.27:100		0.0	
1% aldehyde condensation product of cardanol[25]+1% med. lub. oil+.5% emulsifier[22]+.5% bentonite	2:100	9.3		
1% cashew nut liquid derivative[26]+1% med. lub. oil +.25% emulsifier[22]+.25% bentonite	2:100	2.8		

[1] Mortality corrected by Abbott's (1925) formula. Mortality among 520 water-sprayed eggs in 36 masses was 3.46 per cent; among 519 water-sprayed young nymphs in 30 replicates it was 2.1 per cent; among 92 water-sprayed old nymphs in 12 replicates, 4.3 pe cent. Among 20 water-sprayed adults in 4 replicates no mortality was observed.

[2] *NNOP*. Atlas Powder Co.
[3] *DN* (5%). Dow Chemical Co.
[4] *DN 111*. Dow Chemical Co.
[5] *Shell Agricultural Spray Oil Base*. Shell Oil Co.
[6] *314–500+Vatsol OT*. American Cyanamid & Chemical Corp.
[7] *Basic Pyrethrum Extract No. 191 Odorless*. John Powell & Co.
[8] *Triton B1956*. Rohm and Haas Co.
[9] *Pyrocide Regular*. McLaughlin Gormley King Co.
[10] *Stimtox A*. John Powell & Co.
[11] *New Improved Multicide*. McLaughlin Gormley King Co.
[12] *Syntone*. United States Rubber Co.
[13] *Botano X*. California Spray-Chemical Corp.
[14] *NNOR*. Atlas Powder Co.
[15] *Yellow Cuprocide*. Rohm and Haas Co.
[16] *COCS*. Niagara Sprayer and Chemical Co.
[17] *Pyrax ABB*. R. T. Vanderbilt Co.
[18] *Aresket*. Monsanto Chemical Co.
[19] *Black Leaf 40*. Tobacco By-Products and Chemical Corp.
[20] *Aresklene*. Monsanto Chemical Co.
[21] *Par Oil No. 130 PN*. Amecco Chemicals Co.
[22] *IN-181*. E. I. du Pont de Nemours & Co.
[23] *Gesarol A-20*. Geigy Co.
[24] *Gesarol SH5*. Geigy Co.
[25] *Cardolite 627*. Irvington Varnish and Insulator Co.
[26] *Durite S-2304*. Durite Plastics, Inc.
[27] Adult bugs were killed by this spray as follows:—at 1:19, 100%; at 1:39, 75%; at 1:79, 10%, at 1:159 and 1:319 no mortality of adults was noted.

of oil applied to foliage in sprays of equivalent DDT content.

6. Two copper fungicides, yellow cuprous oxide and copper oxychloride sulphate were tested along with the many insecticides in order to determine their possible effects on squash bugs. Neither of them alone showed any appreciable toxicity to either eggs or active stages. In the one case in which the yellow cuprous oxide was added to mannitan monolaurate containing 1.1 per cent pyrethrins, the apparent effect was to reduce the toxicity of the spray whereas, in the single case of addition of the same fungicide to mannitan monolaurate containing 1.0 per cent rotenone, the apparent effect was the reverse. However, no attempt should be made to generalize on the effectiveness of combination sprays until more data are available.

SUMMARY.—Results of numerous laboratory tests of 26 sprays against squash bug eggs, 21 sprays against newly-hatched nymphs, 10 sprays against nymphs at least 21 days old, and 1 spray against adults are given. None of the materials gave evidence of being really effective ovicides, but several of them, notably those containing pyrethrum, gave high kills of young nymphs. On further testing against older nymphs the same materials failed to kill high percentages of the individuals sprayed. Three formulations of DDT sprays were tested but only the one made from an oil base containing 5 per cent DDT was effective against active stages. It is suggested that for further laboratory or field testing of DDT an emulsible oil be used which contains a much greater amount of DDT in order to apply a large enough dosage to kill older nymphs while at the same time reducing the amount of oil applied to a concentration not injurious to foliage. Two copper fungicides included in the series of tests showed no appreciable toxicity to either eggs or active stages.

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The Geigy Company has published and distributed a booklet entitled "Mechanism of Intoxication of DDT Insecticides in Insects and Warm-Blooded Animals" which is the report of an address delivered by Dr. Paul Läuger at a joint meeting of the Army Committee for Insect and Rodent Control and the OSRD Insect Control Committee" on July 31, 1945. Dr. Läuger is Director of Research for J. R. Geigy, S. A., of Basle, Switzerland, and is perhaps the foremost authority on DDT. Acknowledgement is made in the paper of the part played in the work reported by several of the associates of Dr. Läuger. The subject matter is interesting to all who are concerned with DDT investigations and the Geigy Company deserves our thanks for making it available to the entomological profession.

SCIENTIFIC NOTES

Some New Insecticides for Potato Insect Control

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In 1944, encouraging results were obtained in the use of DDT to control potato insects in New York (Gyrisko *et al.*, 1945). Further work on the use of DDT, a related compound, DDD, and other new materials for potato insect control was continued during 1945 in Suffolk County, Long Island. Some of the work which was of especial interest was the comparison of the toxicity and lasting qualities of various concentrations of DDT and some of these new materials when used as dusts for control of the potato leafhopper, *Empoasca fabae*, and the potato flea beetle. *Epitrix cucumeris*.

MATERIALS AND METHODS.—All DDT dusts were prepared from a dust concentrate said to contain 40 per cent technical DDT which was diluted to the desired concentrations with pyrophyllite. Two brands of the diluent,[2 3] were used in making up separate lots of dust for use in different experiments.

Dichloro-diphenyl-dichlorethane,[4] was first received as an unmicronized concentrate containing 50 per cent of active ingredient but in later trials a micronized concentrate containing 25 per cent of DDD was used. Dilutions were made in a fashion similar and comparable to those in the DDT series.

A material,[5] which found widespread usage on Long Island last season, was prepared from a residue remaining from the refinement of DDT. The crude mixture contained approximately 16 per cent para-para DDT with most of the remainder being other isomers, particularly the ortho-para isomer.

Being of a semi-liquid consistency, the crude mixture was cut with 50 per cent of a mixture of alkylated naphthalenes and anthracenes[1] and was then impregnated on a carrier[2] to make a mixture that could be readily made into dusts. The concentrations of dust used were based on percentages of the crude mixture. Actually a one per cent dust contained 0.16 per cent para-para DDT, 0.6 per cent ortho-para DDT and a remainder that was not identified.

Combinations of sulfur and DDT,[3] both fused and mixed were furnished for these experiments. A recent introduction,[4] containing piperonyl cyclohexenone added to pyrethrum marc and recommended as a substitute for ground pyrethrum flowers was also included in the comparisons. Other dust mixtures compared included 2 per cent beta beta dithiocyano diethyl ether[5] and a sulfur-pyrethrum-rotenone combination, locally referred to as 3-way dust. The latter contained 30 per cent sulfur, 0.75 per cent rotenone and 0.075 per cent pyrethrins and found considerable use on Long Island before the pyrethrum-rotenone shortage. All applications of insecticides were with a six-row traction duster applying 40 to 45 pounds of dust per acre. Plots were 12 rows in width and were replicated two or more times. Insect counts were made by net sweepings before application, 48 hours after treatment and periodically thereafter until the populations of the untreated plots decreased to low levels. For calculation of per cent control, Abbot's formula was employed to com-

[1] Geigy Co. Inc.—*Gesarol*.
[2] Vanderbilt Co.—*Pyrax ABB*.
[3] Carolina Pyrophyllite Co.—*Capyco*.
[4] Rohm and Haas Co.—*Rhothane*, formerly *Z-39*.
[5] John Powell & Co. Inc.—*J. P.*

[1] Socony Vacuum Co.—*APS-202*.
[2] John Mansville Co.—*Celite*.
[3] Stauffer Chemical Co.
[4] Chipman Chemical Co.—*PCH*.
[5] *Lethane B-71*.

Table 1.—A comparison of the toxicity of various concentrations and formulations of DDT, *Rhothane*, *Lethane B-71* and *PCH* for potato flea beetle and potato leafhopper control.

Material and Per Cent Used (Dusts)	Flea Beetle Populations					Leafhopper Populations				
	Before Application[4]	48 hours After	4 days Application	8 days	Per Cent Control in 48 Hrs.	Before Application	48 hours After	4 days Application	8 days	Per Cent Control in 48 Hrs.
"Three Way" 0.75 Rotenone 30.0 Sulfur 0.075 Pyrethrins	1552	108	107	489	92.1	296	64	85	146	82.2
2.0 *Rhothane*[1] Pyrophyllite	1648	129	103	113	91.2	365	73	20	45	83.6
2.0 *Lethane B-71*	890	792	743	580	0.0	230	82	61	147	70.6
25.0 *P.C.H.*	1152	164	500	503	84.0	234	42	35	90	85.3
2.0 DDT Pyrophyllite	2360	86	27	20	95.9	320	2	6	8	99.5
2.0 Residue DDT Pyrophyllite	1430	48	36	42	96.1	406	4	9	16	99.1
2.5 DDT-Sulfur[3]	1340	9	13	14	99.2	392	2	2	1	99.5
2.5 DDT-Sulfur[3]	955	28	7	7	96.7	282	7	2	5	97.9
5.0 DDT-Sulfur[3]	1420	4	1	2	99.6	252	2	0	0	99.3
Untreated check	1780	1572	1045	708	—	273	332	199	168	—

[1] Not micronized.
[3] Mixed.
[3] Fused.
[4] All populations per 40 sweeps of the net.

Table 2.—A comparison of the toxicity of various formulations of DDT, *Rhothane* and *P.C.H.* dusts for potato flea beetle and potato leafhoppers control.

Material and Per Cent Used	Flea Beetles				Leafhoppers			
	Before[3] Application	48 hours After Application	5 days After Application	Per Cent Control in 48 Hrs.	Before Application	48 hours After Application	5 days After Application	Per Cent Control in 48 Hrs.
25.0 *P.C.H.* Dust	5840	420	852	90.3	202	61	154	76.1
1.0 *Rhothane*[1]-*Pyrax ABB*	9040	38	224	99.4	180	8	36	96.5
2.0 *Rhothane*[1]-*Pyrax ABB*	6256	22	184	99.4	138	6	32	96.5
1.0 Residue DDT-*Pyrax ABB*	11320	154	230	98.1	66	6	28	93.9
2.0 Residue DDT-*Pyrax ABB*	9680	106	188	98.3	42	2	27	96.1
1.0 DDT-*Pyrax ABB*	10480	28	166	99.5	68	2	14	97.6
2.0 DDT-*Pyrax ABB*	5040	17	142	99.5	36	2	12	95.1
1.0 DDT-Sulfur[2]	7280	54	162	99.1	33	2	12	95.1
Untreated check	6768	5040	2640	—	84	106	152	—

[1] Micronized.
[2] Fused.
[3] All populations per 40 sweeps of the net.

pensate for population differences in untreated plots before and after application.

RESULTS AND DISCUSSION.—DDT and similar related compounds, residues, produced excellent kills of flea beetles and leafhoppers. Protection remained for 4 to 8 days without appreciable loss in efficiency. There were no significant differences in control between these various materials and none between the concentrations, 1 to 5 per cent, compared in these experiments. (Tables 1, 2, and 3.)

Since control of both insects was above 90 per cent with the lowest dilution used, it was not possible to determine differences in efficiency of the various compounds. From a practical standpoint, however, they are about equally satisfactory since recommended strengths are within the range compared in these experiments.

Although *PCH 25* and *3-way* dust gave good kills of flea beetles and leafhoppers within two days after application, protection over a longer period was unsatisfactory. Population increased rapidly indicating little or no residual effectiveness on the part of these materials. Likewise *Lethane B-71* proved to have only a temporary effect on the leafhopper. Against the flea beetle it was ineffective.

SUMMARY.—In field trials on Long Island, a mixture of DDT isomers, *Rhothane*, and DDT proved to be equally effective in their toxicity and residual action at concentrations usually recommended for control of flea beetles and leafhoppers. *PCH* and *3-way* dusts while giving good kills within 48 hours did not possess the lasting qualities of DDT and its related compounds. *Lethane B-71* was only fair for leafhopper control and did not prove to be effective for the control of the flea beetle.

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Table 3.—A comparison of the toxicity of various formulations of DDT and *Rhothane* for leafhopper and flea beetle control.

Material and Per Cent Used	Flea Beetle				Leafhopper			
	Before Application[3]	After Application 48 hours	After Application 7 days	Per Cent Control in 48 Hrs.	Before Application	After Application 48 hours	After Application 7 days	Per Cent Control in 48 Hrs.
3.0 DDT-Pyrophyllite	4680	2	8	98.8	124	1	8	99.0
5.0 DDT-Pyrophyllite	5160	2	4	99.8	174	2	6	99.3
5.0 DDT-Sulfur[1]	4880	1	0	99.8	212	2	3	99.2
3.0 *Rhothane*[2] Pyrophyllite	3720	1	5	99.8	224	3	2	98.8
5.0 *Rhothane*[2] Pyrophyllite	3535	0	7	100.0	216	3	0	98.8
Untreated check	3400	2985	429	—	187	214	138	—

[1] Mixed.
[2] Micronized.
[3] All populations per 40 sweeps of the net.

Eradication of Boxwood Leafminer and the Boxwood Psyllid

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The growers of boxwood have long needed a good insecticide for the control of the boxwood leafminer, *Monarthropalpus buxi* Labou. The nicotine sulfate-molasses spray recommended by Middleton & Smith (1934) and Hamilton (1935) to be applied as many as 3 or 4 times at short intervals rarely proved adequate especially if rains fell during the period of leafminer emergence.

On April 16, 1945 while spraying for tent caterpillars two heavily miner infested boxwoods were thoroughly sprayed from the inside and outside with a wettable DDT powder[1] at the rate of two pounds of actual DDT per 100 gals. of water. A commercial material was used in this spray as a sticker and spreader at the rate of 1 to 1600. A heavy white residue was deposited on the foliage. Boxwood leafminer emergence began May 7, 1945; and during the entire 3 week period of emergence that followed not a single flying leaf miner was seen around the bushes. An examination of the ground under the boxwoods disclosed hundreds of dead and dying leaf miners. The adult miners were still being killed 6 weeks after the application when emergence ended, although a little over 7 inches of rain fell during that period.

In another experiment DDT was applied to boxwoods in a miscible summer oil solution of 20 per cent DDT[2] diluted 1 to 100 and 1 to 400 with water. This application was made a few days before emergence when the heads of the pupae began to darken. No visible residue was apparent but the same perfect control as with the wettable powder was obtained with the 1 to 100 dilution during the entire 3 week emergence period. A few adults were seen after the second week flying about the boxwoods sprayed with the 1 to 400 dilution indicating some loss in effectiveness at that dilution.

Observations made on DDT treated boxwoods as the miners were emerging indicated that the miners were affected through foot contact with the treated surfaces the same as flies and mosquitoes. They appeared greatly disturbed, lifting one foot after another from the leaf surfaces. Finally, when their wings were dry enough for flight the miners fell to the ground, exhibiting the typical tremors which eventually ended in death. No injury to the boxwoods was observed from any of the treatments, but there appeared to be a tendency for the boxwood mite, *Paratetranychus yothersii* McGregor, to build up to injurious numbers on DDT sprayed plants. In all the applications on boxwoods a small motor powered sprayer was used as a pressure of 200 lbs. per square inch.

CONTROL OF THE BOXWOOD PSYLLID.—The boxwood psyllid, *Psyllia buxi* L., altho not as important a pest as the leaf miner, nevertheless, may cause considerable stunting and disfiguring of new growth by cupping the leaves. Hamilton (1935) recommended spraying with nicotine sulfate and soap to destroy the young numphs just as cupping starts on new growth in the spring. This has not proven effective once the psyllids are in the new growth and cupping begins they are fairly well protected from sprays. The nicotine-molasses sprays applied later for leaf miners did not prove effective for the same reason, unless, as may happen in some seasons, the last spray is applied late enough to catch most of the psyllids in the adult stage. This was discovered by the writer in 1940 when two large isolated boxwoods, heavily infested with psyllids the previous year, were found free of new cupping while other boxwoods remained heavily infested. A search for an explanation of this in the spraying records showed that these two boxwoods had received a late nicotine-molasses spray in early June 1939 when most of the psyllids had reached the adult stage while other boxwoods had not received this spray. This finding led to experiments in 1941 where timing was changed to control the psyllid adults not the nymphs.

A 1 to 400 nicotine sulfate spray, containing *NNO* 1 to 1600 as a spreader and wetter, applied June 20, 1941 (2 weeks after adults were first noticed) first to the outside and then to the inside of the bushes resulted in an excellent kill. In a one square foot area under one bush 97 dead psyllids were counted one-half hour later. These treated bushes were nearly entirely free from new cupping the next spring. Subsequent annual applications to date with nicotine sulfate have shown that complete eradication in a given area can be achieved by this change in timing. Accurate timing to get the adults before egg laying starts is not necessary as observations by the writer[3] have shown that there is an interval of at least 6 weeks after the adults appear before egg laying begins. All shrubbery surrounding the boxwoods should be sprayed at the same time as the boxwoods to get psyllids that may fly from the bushes. DDT as applied for the boxwood leaf miner did not appear to have any residual effect on the psyllids.

SUMMARY AND CONCLUSIONS.—DDT ,as a wettable spray powder diluted at the rate of 2 lbs. of actual DDT per 100 gals. of water plus a sticker-spreader, or as a 20 per cent solution in a miscible summer oil diluted 1 to 100 with water, gives excellent control of the boxwood leafminer with one application applied when the pupal heads have darkened prior to adult emergence.

A 1 to 100 nicotine sulfate spray with spreader and wetter applied about the second week in June against the adult boxwood psyllids results in boxwoods nearly free of new cupping the next spring.

To eradicate both these pests, thorough coverage of the inside and outside of the boxwoods is essential as well as the treatment of all boxwoods in the neighborhood.—1-9-46.

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[1] Supplied by the Geigy Co., N. Y. C.—*Gesarol AK-40.*
[2] *Gesarol Emulsion.*
[3] The life history of the boxwood psyllid will appear in a forthcoming paper.

Effect of Various Dust Mixtures on Incidence of the Cabbage Aphid[1]

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The accelerated multiplication of various species of aphids following the application of certain insecticides and fungicides has been reported by Folsom (1927), Taylor & Blodgett (1930), Moore (1937), Hill & Tate (1943) and others. The purpose of this paper is to report a similar condition with respect to the cabbage aphid, *Brevicoryne brassicae* L. which was observed in connection with a cabbage worm experiment at Geneva, New York, 1945.

The experiment in question was designed to compare a series of dust mixtures which have been used for cabbage worm control with four DDT dust formulations. Three applications of the materials were made at an interval of about two and one half weeks during August and September when insect activity was at its greatest. The dusting was done with a hand duster of the bellows type which was set to apply about 30 to 35 pounds per acre. Each plant received one puff of dust, most of the material being deposited on the upper surface of the leaves. A record of the number of plants infested with aphis was made on September 24 when the infestation was at its peak. Using the number of infested plants as a means of measuring the infestation is not a very accurate method because some of the plants contained a much higher population than others. The method does, however, serve to show the gross differences in infestation between treatments. The results from these counts are shown in table 1.

Table 1.—A record of cabbage plants infested with aphids.

MATERIAL	PER CENT CONCENTRATION	PER CENT PLANTS INFESTED
Cryolite	25	95.3
Cryolite + Shell Horticultural Oil[1]	25 + 1	85.0
Cryolite (micronized)	25	88.1
Lead arsenate	25	86.2
DDT[2]	2	42.2
DDT	1	39.0
DDT + *Velsicol*	1 + 2	34.5
DDT + Shell Horticultural Oil	1 + 2	44.5
Rotenone	0.5	34.3
Benzene hexachloride[3]	3	1.1
Check (untreated)		20.4

[1] Mineral oil having a viscosity 30–35 seconds Seybolt at 100 degrees F.
[2] Prepared from *Gesarol* dust concentrate.
[3] A commercially prepared dust said to contain 8 per cent of the gamma isomer.

It will be observed that practically all of the treated plots had a higher aphis infestation than the untreated. This was particularly true of the plots which were dusted with lead arsenate and cryolite. These were very severely infested and actually sustained considerable commercial damage. The outer leaves of these plants dropped off and the heads became blackened toward harvest time. While the DDT and rotenone-treated plots were more severely infested than the check they were not damaged commercially. It is possible that the same factor or factors which influenced the development of the insect on the arsenical and cryolite plots also operated in the case of the DDT and rotenone-treated plots but since both of these materials have some aphicidal action they may have exercised some check on the development of the insect. A 3-per cent benzene hexachloride dust was the only treatment which appeared to affect the insects adversely, the plots treated with this material being practically free of aphis.

The most obvious explanation for this condition is that the use of certain insecticides destroys the predators and parasites of the aphis, permitting it to develop without any natural barriers. There does, however, appear to be a difference of opinion on this point. Folsom (1930) concluded that the build-up of the cotton aphid following calcium arsenate applications was due to a positive phototropic response of the winged migrants to the dusted plants and killing of the hymenopterous parasites when they emerged in the presence of the arsenical. The predators were unharmed by the arsenical. Moore (1937) also found that the green peach aphis was attracted to potato foliage sprayed with bordeaux. He attributed this to the increased light intensity reflected from the sprayed surfaces. He found, further, that the infestation of the cabbage aphid could be reduced below that of the check or a lead arsenate-lime dust treatment by diluting the arsenical with a black diluent. Dunham & Clark (1941) showed that the cotton aphid multiplied more rapidly on cotton leaves dusted with calcium arsenate than on untreated leaves when the parasites and predators were excluded and suggested that the stimulus might be due to the absorption of the calcium or arsenic or both by the cotton leaves. Smith & Fontenot (1942) observed that the aphis population was much greater and the coccinellid and crysopid population was much less on the calcium arsenate dusted portions of a cotton field than on the undusted, indicating that the arsenical had an adverse effect on the predators.—2-6-46.

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 664, February 2, 1946.

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The Control of Mites on Apple Trees Sprayed with DDT

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One of the noteworthy results accompanying the use of DDT on apple trees during the season of 1944 was the development of mites on the sprayed trees. The foliage was bronzed on most of the trees which had been sprayed with concentrations of DDT ranging from 6.4 ounces to 24 ounces in 100 gallons of water. Mite injury was confined to trees sprayed with DDT. In late August and early September counts revealed mite populations on trees which had received two or more applications of DDT as follows: 878 to 5379 per 100 leaves in one orchard and 120 to 1477 in another orchard as compared to only 2 to 7 on 100 leaves from trees which had received the regular arsenical sprays through the season. Two species of mites were present, the European red mite, *Paratetranychus pilosus* C. & F., and the apple mite, *Tetranychus schoenei* McG., the latter being 5 times more numerous than the former in one of the orchards and 10 times more numerous in the other orchard.

In the light of this experience it seemed desirable to attempt to suppress or prevent development of mites in some of the plots sprayed with DDT in 1945. The DDT schedules designed for control of codling moth began in most plots in April 30 with the first cover spray or on May 15, the date of the second cover spray, and were concluded with the seventh cover on August 7 or with the eighth cover on August 17. Materials intended for mite control were added in the third, fifth, and seventh covers, and also in the eighth cover wherever it was applied. There were, however, four exceptions to this schedule. In plot 31,

Table 1.—Effect of addition of various ingredients to DDT sprays in suppressing mite development on the foliage of York Imperial apple trees at Winchester, Virginia.

TREATMENTS[1] Material and Quantity per 100 Gallons of Spray	APPLIED IN COVER SPRAYS—	MITES PER 100 LEAVES		
		European red mite	*Tetranychus schoenei*	Total
25% DDT, 2 lbs. Lead 3 lbs. 40% *DN-Dry Mix*[1] 0.67 lb.	1–8 5, 7, 8	12	7	19
25% DDT 4 lbs. 40% *DN-Dry Mix*[2] 0.67 lb.	1–8 5, 6, 7, 8	57	16	73
DDT-xanthone mix 2 lbs.	3–8	84	50	134
25% DDT 4 lbs. 20% *DN-111*[3] 1.25 lbs.	2–7 3, 5, 7	120	23	143
40% DDT 2.5 lbs.[4] 20% *DN-111* 1.25 lbs.	1–8 3, 5, 7, 8	187	56	243
Lead 4 lbs. Lime 2 lbs. Lead 3 lbs. Lime 2 lbs.	1–8 1–8	294	75	369
25% DDT 4 lbs. 20% *DN-111* 1.25 lbs.	2–7 3, 5, 7	294	90	384
40% DDT[4] 2.5 lbs. Xanthone 1 lb.	1–8 3, 5, 7, 8	107	534	641
25% DDT 4 lbs. Xanthone 1 lb.	2–7 3, 5, 7	153	555	708
25% DDT 4 lbs. Summer oil emulsion[5] 3 qts.	2–7 3–7	701	322	1023
40% DDT 2.5 lbs.	1–8	1433	1055	2488
40% DDT 2 lbs.	1–8	1739	1059	2798
25% DDT 1 lb. Lead 3 lbs.	1–8	2235	573	2808
25% DDT 4 lbs.	2–7	1820	1549	3369

[1] Bordeaux, 2-4-100 formula, was added in the fourth and sixth cover sprays in plots 10, 25, 27, 28, 31, 32, 36, 38, and 39.
[2] Dinitro-ortho-cyclohexylphenol.
[3] Aminesalt of dinitro-ortho-cyclohexylphenol.
[4] *AKZ-40.*
[5] *Orthol-K.*

the dinitro material was added in four successive applications, beginning with the fifth cover on June 25, and in plot 39 a similar schedule was employed, except that the dinitro material was omitted in the sixth cover. In plot 36, oil was added in five successive applications, beginning with the third cover, while in plot 40, *xanthone* was included in all sprays from the third to the eighth covers, inclusive.

The DDT preparations were washed through the strainer or sifted into the tank while filling with water and the materials for mite control were added in a similar manner when the tank was nearly full of water. The materials may be described briefly as follows: a preparation containing about 40 per cent dinitro-o-cyclohexylphenol,[1] two preparations containing about 20 per cent amine salt of dinitro-o-cyclohexylphenol,[2] xanthone,[3] and 83 per cent summer oil emulsion.[4] Sources of the DDT formulations were as follows: 25 per cent DDT,[5] *AKZ-40*,[6] *DDT-xanthone mix*.[7]

DISCUSSION AND RESULTS.—During the last four days of August 100 leaves selected at random were examined for each of the treatments and the results are summarized in the accompanying table. Approximately 61 per cent of the mite population was the European red mite, the remainder being *Tetranychus schoenei*. The results are not conclusive because they represent only one season's work. Furthermore the abnormal season was unfavorable for mite development from May through July and during part of August, and as a result severe bronzing failed to occur on the foliage as compared to the damage of the previous year. On the other hand, mites were more generally distributed than in 1944 as indicated by the larger number occurring on foliage which received arsenical sprays only.

Only the York Imperial variety was included in the test plots, except in plot 31 which contained two Grimes Golden trees. No injury was evident on the fruit or foliage that could be attributed to the spray ingredients used.

Codling moth control was excellent for all the treatments listed, except the treatment for plot 40 in which 8.9 per cent of the fruit graded wormy and an additional 8.6 per cent showed "stings." Laboratory tests of the past two seasons indicate that none of the combinations greatly alter the initial toxicity of DDT deposits to young codling moth larvae except summer oil emulsion which consistently lowered effectiveness of the DDT spray to which it was added at the rate of 3 quarts and 6 quarts of the emulsion in 100 gallons. In orchard tests, however, reduction in efficiency of DDT against the young larvae may be offset by the ovicidal value of the oil.

It will be noted in the accompanying table that the population density of mites did not vary with the concentrations of DDT used in the experiments; for example, mites were as abundant in plot 38, where the DDT concentration was only 4 ounces, as in plots 28 and 32, where the concentration was 1 pound in 100 gallons.—1-14-46.

[1] *DN Dry Mix No. 1.*
[2] *DN-111* and *C-336.*
[3] *Genicide.*
[4] *Orthol-K.*
[5] Du Pont
[6] Geigy Co., *AKZ-40.*
[7] General Chemical Co.

Compatibility of DDT and Fungicides on Potatoes

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The question of the compatibility of DDT and fungicides on potatoes is of concern to both the entomologist and the plant pathologist. Recent work on DDT has shown that control of the potato leafhopper *Empoasca fabae* (Harr.), by bordeaux left much to be desired, and the use of new organic fungicides, such as *Dithane* plus zinc sulfate-lime, has shown that better disease control and yield could be obtained than by the use of bordeaux. Thus, these new materials need critical evaluation on potatoes, both when used alone and when used in combination, as they seem likely to supplant bordeaux to a large extent. This problem has been under investigation in Delaware the past two seasons.

EXPERIMENTS AND RESULTS.—Three experiments have been conducted: the first on late Dakota Red potatoes in 1944; the second on early Irish Cobbler potatoes in 1945; and the third on late Dakota Red potatoes in 1945. During these years, three distinct sets of conditions of leafhopper infestation and foliage disease infection were encountered; in the first test both leafhoppers and early blight disease, *Alternaria solani* (Ell. & Mart.) Jones & Grout, were present; in the second test leafhoppers only were serious; and, in the third test, only early blight disease was present. These three distinct sets of conditions made possible the evaluation of materials for leafhopper control alone, for disease control alone, and for joint leafhopper and disease control.

Table 1.—Effect of DDT on the control of leafhoppers and early blight disease when used alone and combined with fungicides on *Dakota Red* potatoes. Georgetown, Delaware, 1944.

MATERIAL	LEAFHOPPERS PER 21 PLANTS	PERCENTAGE DEFOLIATION	TOTAL YIELD (LBS./21 PLANTS)
	(9-8-44)	(10-11-44)	
Check	10.5	42	9.1
DDT	1.0	45	11.6
Compound A	5.7	15	12.7
Compound A+DDT	1.7	10	12.8
Zerlate[1]	5.3	12	11.4
Zerlate+DDT	2.3	10	12.4
MSD at 5 per cent point	—	11	2.6

[1] Zinc dimethyl dithiocarbamate.

The data in the first test (Table 1) show that leafhopper control by DDT was essentially the same whether used alone or in combination with the fungicides, that control of early blight by the fungicides was the same when they were used in combination with DDT as when used alone, and that DDT did not control early blight disease. The most striking thing in this test was the growth of the plants receiving DDT, either alone or combined with the fungicides—they were taller, broader, and had larger and flatter leaflets than unsprayed plants or those receiving fungicides alone.

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All three experiments were laid out in a replicated, randomized block design, each material being replicated four times on 21-plant plots. The treatments were all used as sprays and applications were made on approximately a seven to ten-day schedule. Five applications were made in the first test and six in the last two. The fungicides were used at rates equivalent to 1.5 to 100 active ingredient and DDT[3] was used at 0.75–100 actual DDT. The amount of material was adjusted to the stage of growth of the plant; generally, 75 gallons per acre were used at the first application and 200 gallons per acre at the last application.

Table 2.—Effect of DDT and fungicides on control of leafhopper injury and on yield of *Irish Cobbler* potatoes, Newark, Delaware, 1945.

Material	Leafhopper Counts	Percentage Defoliation	Yield (Bu./Acre)
	(per leaf)	(July 9)	(Aug. 2)
Check	27	77	216
DDT	4	5	383
Bordeaux	21	32	257
Bordeaux+DDT	7	7	346
Compound A	16	37	263
Compound A+DDT	5	12	373
Zerlate[1]	23	32	301
Zerlate+DDT	7	0	415
Dithane[2]+$ZnSO_4$−Lime	18	50	274
Dithane+$ZnSO_4$−Lime +DDT	6	0	408
MSD at 5 per cent point			44
MSD at 1 per cent point			59

[1] Zinc dimethyl dithiocarbamate.
[2] Disodium ethylene bisdithiocarbamate.

The data in the second test (Table 2) show that the control of leafhoppers by DDT was not affected by combining it with a fungicide, and that the yield response to leafhopper control by DDT was not significantly affected by combining DDT with the fungicide. As in the first test, the plants receiving DDT, either alone or with the fungicide, were taller, broader, and had larger leaflets than those unsprayed or sprayed with fungicides alone.

The data in the third test, where leafhoppers were not present, show that DDT alone did not control early blight disease nor did it affect the control shown by the fungicides. In this test the plants sprayed with DDT alone or combined with the fungicides had the same growth apperance as those unsprayed or sprayed with the fungicides alone.

Table 3.—Effect of DDT and fungicides on control of early blight disease on *Dakota Red* potatoes, Georgetown, Delaware, 1945.

Material	Percentage Defoliation	Yield (Lbs./21 Plants)
	(10-11-45)	
Check	77	11.0
DDT	60	14.2
Bordeaux	23	14.0
Bordeaux+DDT	13	17.5
Compound A	30	19.1
Compound A+DDT	27	15.1
Zerlate[1]	30	12.1
Zerlate+DDT	23	11.6
Dithane[2]+$ZnSO_4$−Lime	13	16.1
Dithane+$ZnSO_4$−Lime+DDT	10	16.8

[1] Zinc dimethyl dithiocarbamate.
[2] Disodium ethylene bisdithiocarbamate.
[3] *Deenate.*

Discussion and Conclusions.—The excellent growth of plants sprayed with DDT under conditions of leafhopper infestation suggests that DDT might be a growth promoter. The better growth, however, may be simply the result of leafhopper control, for when leafhoppers are not present plants sprayed with DDT are no different in appearance from those unsprayed or sprayed with fungicide alone. It is apparent, then, that leafhoppers have a more serious effect on plants than has heretofore been thought.

The data obtained under the conditions of these experiments are interpreted as follows: DDT gave excellent leafhopper control and high yield responses; DDT has no fungicidal value; DDT is noninjurious to potatoes when used alone or in combination with the fungicides tested; DDT and several inorganic and organic fungicides are compatible since each material was as effective when used in combination as when employed alone.—1-25-46.

The Control of the Cowpea Curculio

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Although cowpeas are not grown as a commercial crop in Virginia, this plant is a favorite in many home gardens. The cowpea curculio, *Chalcodermus aeneus* Boh., has caused considerable losses of edible peas in some seasons, especially in the southeastern Counties.

Work was started late in 1943 to determine the importance of the insect and to work out methods of control that would reduce the losses of edible peas. Only a limited infestation existed at Chatham in the summer of 1944 and plot treatments with insecticidal dusts failed to yield satisfactory information on the performance of insecticidal materials. Dust treatments could not be confined satisfactorily to the plots to which they were applied and reduction of curculio population also took place on the untreated controls. Arant (1938), working with the curculio in Alabama experienced the same difficulty.

In 1945 spraying was substituted for dusting and a much better evaluation of the efficiency of four selected insecticides was obtained. Twelve replicated plots of 5 rows of blackeye cowpeas 25 feet in length were planted early in May. Four insecticidal treatments and one untreated control were randomized in each of the 12 plots. Sprays were applied 3 times to each plot at intervals of one week starting when the first small pods were forming. All of the sprayed materials adhered well to the foliage even though rains followed the treatments.

Materials Used.—Wettable DDT, 25 per cent,[2] sodium silicofluoride (97 per cent), natural cryolite,[3] and basic copper arsenate were the insecticides used in the tests. All were used at the rate of 6 pounds of the dry material to 100 gallons of water. Application

[1] Acknowledgment is made to Dr. Boyd Harshbarger of the Virginia Agricultural Experiment Station for his statistical analysis of the data.
[2] Dupont's *Deenate 25W.*
[3] *Kryocide 593-1.*

of the spray was made with compressed-air and knapsack sprayers equipped with *Mohawk* adjustable nozzles. Spraying was done from both sides of the rows in order to insure coverage of foliage, pods, and stems. Six gallons of each spray was required for each application; *i.e.*, 2 quarts of spray material was used for each row of 25 feet.

METHOD OF EVALUATION.—Maturing cowpea pods were picked 3 times from each plot at intervals of 10 days. Each lot was held separately in a wire basket over a metal pan. Emerging prepupae of the curculio were recorded and removed daily. Prior to making subsequent pickings, yield weights of dried peas and pods were recorded.

Table 1.—Summary of insecticidal control results—12 replications.

MATERIAL	TOTAL PREPUPAE	AVERAGE PREPUPAE	ADJUSTED AVERAGE PREPUPAE
25 per cent DDT	358	29.83	4.92
Sodium silicofluoride	246	20.50	3.86
Untreated control	539	44.92	5.99
Cryolite	293	24.42	4.50
Basic copper arsenate	132	11.00	3.02

Difference in adjusted average prepupae required for significance—.79

DISCUSSION.—Sodium silicofluoride is the insecticide generally recommended for control of cowpea curculio in commercial plantings of cowpeas (Arant 1938b). Although the performance of sodium silicofluoride, applied as a spray to cowpea plots at Chatham, was superior to natural cryolite and DDT, this insecticide was significantly inferior to basic copper arsenate in reducing cowpea curculio infestation. No burning of cowpea foliage followed the spraying of basic copper arsenate or of the other insecticides. Yield data showed no significant increase or decrease for any of the treatments. Plants sprayed with basic copper arsenate retained their leaves much better than plants in the untreated controls or those to which other insecticides were applied. Apparently, the basic copper arsenate acted as a fungicide that prevented early defoliation of the plants by a leaf-spot disease.—1-9-46.

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Individual Comparisons of Grouped Data by Ranking Methods

FRANK WILCOXON
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A recent publication (Wilcoxon 1945) describes a method for determining the significance of the difference of the means of two treatments by assigning rank numbers 1–2–3 · · · n to the numerical data of the experiment and summing up the rank totals for the two treatments separately. In the case of paired comparisons, the rank numbers were assigned to the differences between members of a pair. However, a type of experiment which probably occurs more often than those mentioned previously is the following: The results are obtained in distinct groups, as for example, when two fumigants are tested at several different concentrations, or when two treatments are compared at different times or localities; and there are two or more replications at each concentration, time, or locality.

Application of the rank method to an experiment of this type in which two DDT preparations were compared on *Tribolium confusum*, is illustrated in the following table:

CONCENTRATION	PREPARATION A	RANK	PREPARATION B	RANK
25 mg/100 cc	30% kill	(3)	34% kill	(4)
	50% kill	(6)	42% kill	(5)
	18% kill	(1)	53% kill	(7)
	26% kill	(2)	63% kill	(8)
50 mg/100 cc	33% kill	(1)	66% kill	(7)
	44% kill	(3.5)	80% kill	(8)
	44% kill	(3.5)	60% kill	(5)
	42% kill	(2)	62% kill	(6)
100 mg/100 cc	50% kill	(2)	74% kill	(5)
	56% kill	(3)	84% kill	(7)
	44% kill	(1)	92% kill	(8)
	64% kill	(4)	77% kill	(6)
Rank total		(32)		(76)

The rank numbers are assigned within the groups, giving three sets of rank numbers from 1 to 8. Referring to the probability table below, it is seen that the probability of a total score of 32 or less in the case of 3 groups and four replicates per group is less than .0134, since the latter is the value for a score of 39. We may therefore infer that these treatments differ significantly with odds greater than 100–1.

Table of cumulative probabilities of rank totals for grouped data.

REPLICATES PER GROUP	NUMBER OF GROUPS 2 Total	2 P	3 Total	3 P	4 Total	4 P
2	6	.056	9	.0092	13	.0077
2	—	—	10	.037	14	.0277
2	—	—	11	.120	15	.0709
3	13	.015	21	.0088	30	.0099
3	14	.040	22	.020	32	.0374
3	15	.090	23	.041	33	.0637
4	24	.016	39	.0134	54	.010
4	25	.029	40	.0227	56	.024
4	26	.050	42	.0544	58	.050

The method of calculation of probabilities may be illustrated by a simple case. Suppose that there are two replicates in a group. The possible rank totals for a treatment in one group are 3, 4, 5, 6, 7. The possible totals and the number of ways in which each may be obtained are given by the expansion of:

$$\frac{x^3(1-x^3)(1-x^4)}{(1-x)(1-x^2)}$$

which gives $x^3+x^4+2x^5+x^6+x^7$. The exponents of x are the possible totals, and the coefficients of x give the number of ways of obtaining each total. Since each combination of rank numbers in one group may occur with any other combination in another group, the distribution of totals for two or more groups is obtained by multiplying the expression given above by itself as many times as there are groups. Similar expressions may be found for cases involving more than two replicates per group. The probability of obtaining any particular total is twice the number of ways of obtaining the total, divided by all the possible ways of getting all the possible totals. The method of ranks is, of course, an approximate one; but the loss of information is not as great as might be supposed.—1-25-46.

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Two Industry Problems Caused by Release of DDT

CHARLES L. SMITH, *Agricultural Insecticide & Fungicide Assn., New York, N. Y.*

The sudden end of the war and subsequent release of DDT for unrestricted civilian use imposed a number of problems on industry.

It is my purpose here to briefly bring to your attention two of these industry problems with which the AIF Association has been particularly concerned.

As you know, the AIF during the war undertook the task of keeping agricultural interests advised of the supply situation with regard to insecticides and fungicides and likewise of keeping industry informed of the important need for scarce items in a particular locality. This service aided materially in securing proper distribution of needed chemicals.

The sudden release of DDT threatened to cause severe interruption of normal advance season purchasing of standard insecticides.

Distributors and dealers have been withholding purchases and local remixers have not produced stockpiles because of uncertainty as to the materials growers will use in 1946.

Apparently many growers were waiting for information from their state experiment station and extension service as to whether DDT would be recommended in 1946 to replace previous spray schedules.

Agricultural Insecticide and Fungicide Association contacted the entomologists and extension men in each state requesting that advance information be furnished on the place of DDT in 1946 recommendations. Replies have been received from over 35 states and this information has been compiled on a state by state basis and supplied by bulletin and through the *A.I.F. News* to members of the industry and the various state agencies.

It appears that DDT will be recommended on potatoes fairly generally, also by some states to control onion thrips and for spraying of ornamentals, particularly greenhouse crops. It is also being recommended quite generally for spraying of dairy barns for fly control, and for poultry houses and other livestock quarters for the same purpose and to control bedbugs and other insects affecting farm animals.

It is not being recommended generally as a replacement for standard controls for fruit or vegetable insects. Many states are giving directions for use based on research experience and listing DDT as an alternate spray program with suggestion that it be used in an experimental way by the grower on part of his crop. A number of states are recommending the use of DDT for control of grape leafhoppers and for control of Oriental fruit moth and Japanese beetles on peaches.

A few states have also indicated that its use will be recommended on young cabbage and cauliflower for control of cabbage worms and on corn for European Corn Borer.

Based on this survey it is safe to conclude that DDT will not affect the overall consumption of standard insecticides this year.

We have received a number of comments on the value of this survey and wish to take this opportunity of thanking those of you who may have contributed information.

Another problem caused by the sudden release of DDT was the proper labeling of DDT formulations for guidance and protection of the civilian consumer.

The civilian market as you know was flooded immediately following the release of DDT by a wild assortment of DDT formulations, many of them improperly labeled and many of them worthless. Most of these were products hastily put on the market by companies new to the insecticide field.

We are particularly concerned with the proper labeling of DDT insecticides from the viewpoint of public health.

The Agricultural Insecticide & Fungicide Association is not in a position at the present time to make a definite statement on the toxicity of DDT. Throughout the war, aside from small research quantities, all the DDT produced was used on a large scale by the armed forces. Therefore, practically all the toxicological data, necessarily, was accumulated by the federal agencies, which are the best equipped to furnish such information for the protection of the public. The industry is following their recommendations.

I would like to review what the industry is doing to support the government program.

Many chemicals present no hazards in normal handling, storage and use, and for these products no precautionary labels are necessary. Industry recognizes, however, that handlers and users do need proper warnings where hazards do exist and that the most practical means for disseminating this information is on the labels. This situation is now more important than ever because of the great number of new chemical products entering the markets.

Accordingly, a committee of the Manufacturing Chemists Association, composed of toxicologists, chemists and physicians, in cooperation with interested Government agencies, carefully analyzed the problem and adopted a specific program for the use of warning labels for hazardous chemicals.

Their investigation showed that the use of the warning "Poison" on products not falling in that classification of hazard caused the user to become careless, resulting sooner or later in an accident. The classification of all chemical or drug hazards under the single warning "Poison," which was useful in the age of inorganic chemicals, is highly unsatisfactory and actually a public danger when applied arbitrarily to the consumer hazards of the organic chemical age which we are now entering.

Ten separate and distinct classes of exposure hazards to chemicals were found and only one of them is correctly described by the label "Poison." These classes are:

1. Flammable liquids and oxidizing agents which support combustion.
2. Flammable solids and oxidizing agents as classified by the ICC.
3. Vapors immediately toxic or extremely irritating even on exposure for a short time or to low concentrations.
4. Vapors hazardous from prolonged or repeated exposures, or exposures to higher concentrations.
5. Vapors physiologically inert.
6. Harmful dusts.
7. Skin irritants—corrosive.
8. Materials causing skin irritations after repeated or continued contact.
9. Materials toxic through vapor inhalation or skin absorption.
10. Toxic if taken internally. Applies to materials covered by statutory definition of poison liable to be destructive of human adults in doses of 60 grains or less (4 gms.) or to any material toxic in amounts to be taken internally through easily anticipated errors.

The industry represented by Manufacturing Chemists Association and Agricultural Insecticide & Fungicide Association holds that warning labels should state only those hazards and necessary precautions applicable to each specific hazardous chemical product.

What is meant by specific cautions? Two examples which I will use here were cited by L. L. Hedgepeth in a similar paper presented before the North Central States Association of Enforcement officials. These were carbon tetrachloride and beta-naphthylamine.

"The class of chlorinated hydrocarbons represented by carbon tetrachloride can and does cause serious physiological disturbances in man. Use of them in poorly ventilated areas (concentration exceeding 100 ppm in air) will result in toxic symptoms, including dizziness, nausea, visual aberration, and in cases of continued exposure to high concentration, fatty degeneration of the liver. Use of them in well ventilated areas or hooded equipment offers no hazard.

It is at once obvious that the public will be best served by a specific warning. Therefore, under voluntary written agreements with the Surgeon General of the U. S. Public Health Service all producers have agreed to label all packages holding more than 16 fluid ounces of carbon tetrachloride in part as follows:

"Volatile Solvent
Use with Adequate Ventilation
Avoid Prolonged Breathing of Vapor."

Similarly, beta-napthylamine presents a specific hazard—that of absorption through the skin or lungs on repeated contact, causing bladder tumors. According to the manufacturers' physicians these are incurable.

This is a good example of the inadequacy of the use of a general warning to protect the user. The label worked out by the Manufacturing Chemists Association group reads in part:

"Contents Harmful
Repeated Absorption May Result in Bladder Tumors
Avoid Breathing Dusts or Vapors
Do Not Take Internally"

In neither of the above cases would the poison label, skull and crossbones, and antidote offer the protection which is needed for their safe handling.

Similarly DDT requires a special set of protective precautionary warnings for the consumer. These were worked out by the Insecticide Division, Production & Marketing Administration, U.S.D.A. in cooperation with officials of the U. S. Public Health Service, the Food and Drug Administration and our Joint DDT Committee representing Mfg. Chemists Association, Agricultural Insecticide & Fungicide Association, and the National Association of Insecticide & Disinfectant Manufacturers.

The recommended precautionary labeling for DDT preparations follows:

"For straight DDT Technical

CAUTION: DDT is toxic and when in solution can be absorbed through the skin.
Avoid inhaling dusts, and mist from spray.
Avoid contamination of foodstuffs.

For Petroleum Oil Solutions and Emulsions containing not more than 25% DDT Technical

CAUTION: This solution if brought into repeated or prolonged contact with the skin can cause toxic symptoms.
Avoid excessive inhalation and skin contact.
In case of spillage on the skin wash with soap and water.
Avoid contamination of foodstuffs.
Do not use on household pets or humans.

For Petroleum Oil Solutions and emulsions containing more than 25% DDT Technical

CAUTION: This solution if brought into contact with skin can cause toxic symptoms.
Avoid inhalation and skin contact.
In case of spillage on the skin wash immediately with soap and water.
Avoid contamination of foodstuff.
Do not use on household pets or humans.

For Combustible Mixtures

CAUTION: This solution if brought into contact with skin can cause toxic symptoms.
Avoid inhalation and skin contact.
In case of spillage on the skin wash immediately with soap and water.
Avoid contamination of foodstuffs.
Do not use on household pets or humans.
Do not spray into or near fire or open flame.
Do not smoke while spraying.

For Dust and Powder Formulations

CAUTION: Avoid excessive inhalation.
Avoid contamination of foodstuffs.

If the preparation contains other hazardous ingredients or solvents, appropriate additional cautions must be added to the foregoing.

In addition, these cautions should be prominently displayed in bold type, preferably in red, on a contrasting background.

Industry would like to see this labeling made a mandatory requirement in all states. We believe that the public will be well protected by its adoption, in that the consumer will be warned on each package as to the inherent dangers of the product and the precautions necessary to prevent accidents.—1-9-46.

DDT and Lead Arsenate Compared for Control of the Pecan Nut Casebearer: 1945 Tests

C. B. NICKELS, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Spraying experiments to compare DDT (1-trichloro-2,2-bis(*p*-chlorophenyl) ethane) with lead arsenate for the control of the pecan nut casebearer, *Acrobasis caryae* Grote, were conducted in Texas in 1945. The experiments were carried on in central Texas in an orchard having a medium infestation and a light nut crop, and in southern Texas in an orchard having heavy infestation and a large crop.

MATERIALS.—Technical DDT in the form of a micronized 1:1 mixture with pyrophyllite was used. One spray formula contained DDT 24 ounces, glue 1 pint, and summer oil (a commercial emulsion containing 88 per cent of oil), 2 quarts per 100 gallons. Another formula contained DDT 16 ounces, nicotine sulfate 13 ounces, glue 1 pint, and summer oil 2 quarts per 100 gallons. Lead arsenate (acid) was used at the rate of 6 pounds per 100 gallons. A mixture of lead arsenate, 6 pounds was used with nicotine sulphate, 13 fluid ounces and summer oil, 3 quarts per 100 gallons. Zinc sulfate, 2 pounds per 100 gallons was added to all sprays, primarily to control pecan rosette, but it also reduced the danger of arsenical burning.

METHODS.—At Comanche, Texas, spray treatments were replicated 11 times on Burkett variety trees, and at Crystal City, Texas, spray treatments were replicated 8 times on Humble variety trees. All the spraying was done from the ground at a pressure of 500 to 600 pounds, a power machine and a single-head gun being used. A single spray treatment was applied at Crystal City on April 26, one day after 21 per cent of the first-generation eggs had hatched, and at Comanche on May 28, two days after 41 per cent of the first-generation eggs had hatched.

The following criteria were used in determining effectiveness of the spray treatments: (1) The percentages of nuts retained in tagged clusters of nuts after the end of the feeding period of the first-generation larvae and at harvest. A few days before the first-generation larvae began to feed on the newly formed nuts, serially numbered tags were placed on 50 nut clusters on each of 8 to 11 trees for each treatment. (2) The yields of nuts harvested from each tree used in the tests. The size of the trunk of each tree was measured and nut-yield records were calculated on a cross-sectional-area basis, which eliminated much of the variation resulting from variation in tree size.

Data pertaining to the retention and harvest yield of nuts are summarized in table 1.

DISCUSSION OF RESULTS.—In the experiment at Comanche, trees sprayed with DDT or lead arsenate retained an appreciably higher percentage of nuts in the clusters and produced a considerably greater yield per unit area than those not sprayed. The results indicate that 24 ounces of DDT per 100 gallons of spray may be as effective as 6 pounds of lead arsenate in controlling a medium infestation of the nut casebearer.

In the experiment at Crystal City, the data indicate that the two DDT spray mixtures were about equally effective, and somewhat more so on the whole than either lead arsenate alone or with the nicotine sulfate and oil in the control of the nut casebearer. Lead arsenate with nicotine sulfate and oil was more effective than lead arsenate alone.

EFFECT OF SPRAYS ON TREES.—Observations in 1945 in central and southern Texas showed no evidence of injury to pecans from the use of any of the spray treatments discussed in this paper. Lead arsenate may injure pecan foliage seriously in areas where the climate is humid. It was obesrved in the orchard at Comanche that trees receiving a spray application of lead arsenate with zinc sulfate retained leaves longer than unsprayed trees and trees sprayed with DDT.

Table 1.—Effectiveness of various spray treatments in controlling the pecan nut casebearer as determined by retention of nuts in tagged clusters and harvest yield of nuts. 1945.

SPRAY TREATMENT	NUTS RETAINED IN TAGGED CLUSTERS		NUTS PER SQUARE FOOT OF TRUNK SECTION
	June	Oct.–Nov.	
	Per Cent	*Per Cent*	*Pounds*
Orchard at Comanche, Texas, Burkett Variety			
DDT, glue, oil	66.9	40.7	21.8
Lead arsenate	59.9	40.3	21.4
Check (no treatment)	42.4	18.4	12.1
Difference required for significance:			
P=0.01	17.6	10.6	—
P=0.05	12.4	7.8	—
Orchard at Crystal City, Texas, Humble Variety			
Lead arsenate, nicotine sulfate, oil	74.4	59.4	94.5
Lead arsenate	66.2	46.8	68.8
DDT, glue, oil	82.6	61.7	114.9
DDT, nicotine sulfate, glue, oil	81.3	69.3	98.2
Difference required for significance:			
P=0.01	9.9	10.3	18.9
P=0.05	7.3	7.6	13.9

CONCLUSIONS.—The data included in this paper indicate that DDT and lead arsenate were equally effective in the control of a medium infestation of the first-generation of pecan nut casebearer, and that DDT was much more effective than lead arsenate and slightly better than a mixture of lead arsenate, nicotine sulfate, and summer oil in the control of a severe infestation of the first-generation of this insect.—1-7-46.

Sabadilla and DDT to Control the Squash Bug[1]

R. R. WALTON, *Oklahoma Agricultural Experiment Station, Stillwater*

During 1945, sabadilla, DDT and *Pyrocide* dusts were compared in three types of tests as to their effectiveness on the squash bug, *Anasa tristis* Degeer. Sabadilla dusts were prepared by diluting the concentrate of sabadilla and lime with *Pyrax*. *Gesarol A-10-Dust* was used as the 10-per cent DDT dust and was diluted with *Pyrax* to form the 5 per cent DDT dust. Ten per cent *Pyrocide* dust was used.

In field-cage tests, small to medium squash plants, heavily infested with squash bugs, were dusted with rotary hand dusters. Immediately after treatment, the plants were covered with screened cages to prevent escape of the bugs. Approximately 1 ounce of dust was applied to each plant. With the exception of one test, the test periods varied from 64 to 72 hours in length. At the end of the test periods, cages were removed and the numbers of dead and living bugs recorded. The results are given in table 1.

The same materials were used in a laboratory test on adult squash bugs. Table 2 shows the percentage mortality over a period of 8 days.

In late summer the insecticides were compared in a small field test. The test was made on a single row of late squashes containing 16 plants. The row was divided into four groups of four plants each; the order being such that no two adjacent plants were in the same group. Three of the groups were dusted, while the other was left untreated. A number of other untreated plants were at a distance of 70 to 80 feet from the test plot. A sheet of heavy blotting paper of the type used in botanical plant presses was placed as a trap under each squash plant. The numbers of living bugs under the traps were recorded at intervals of 2 to 4 days. Table 3 gives the results.

The data show that if plants are thoroughly dusted, control can be obtained with dusts containing as low as 5 per cent sabadilla. DDT was less effective on the larger nymphs and adults during a period of 64 to 72 hours after treatment. However, tests extending over a longer period of time indicate that DDT continues to kill squash bugs for several days after treatment and ultimately establishes effective control.

[1] Approved by the Director of the Oklahoma Agricultural Experiment Station.

Table 1.—Percentage mortality in field-cage tests.

Date of Test	Sabadilla 10 Per Cent			Sabadilla 5 Per Cent			DDT 5 Per Cent			Pyrocide 10 Per Cent			Untreated All Stages
	Instars			Instars			Instars			Instars			
	1–3	4–5	Adults	1–3	4–5	Adults	1–3	4–5	Adults	1–3	4–5	Adults	
July 12	100.0	98.2		100.0	100.0	86.5				100.0	60.1	50.3	4.1
July 14		100.0	100.0	100.0	96.7	50.4	100.0	80.3	28.9	95.2	40.4	0.0	2.3
July 14	100.0	100.0	100.0	100.0	90.3	50.2							
July 16	100.0	100.0	97.2	100.0	95.3	100.0	100.0	70.4	60.2	70.7	31.2	0.0	0.0
July 17	100.0	100.0	98.4	95.1	75.3	81.4	84.3	33.4	50.2				2.0
July 17	100.0	98.0	100.0	100.0	95.0	67.1	97.2	25.9	67.6	73.1	48.0	22.1	
July 18[1]	100.0	100.0	85.8	100.0	91.4	96.7	100.0	90.1	93.4				
Average	100.0	99.4	96.9	99.3	92.0	76.0	96.3	60.0	60.1	84.8	44.9	18.1	2.1

[1] Counts made 114 hours after application.

Table 2.—Percentage mortality[1] at specified intervals in a laboratory test.

Interval after Treatment	1 Day	2 Days	3 Days	4 Days	6 Days	8 Days
Sabadilla 10%	47.9	75.1	80.4	85.2	85.2	86.0
DDT 10%	2.0	21.2	33.4	44.1	70.3	82.1
Pyrocide 10%	0.0	0.0	0.0	10.7	19.5	20.1
Untreated	0.0	0.0	0.0	6.0	6.0	10.1

[1] Based on two replicates of approximately 30 insects.

Table 3.—Numbers of living squash bugs trapped beneath boards placed under squash plants that were dusted August 5, 7 and 17.

Dust Used	August[1]											Sept.
	5	7	9	11	14	16	20	23	26	29	31	3
Sabadilla 10%	78	28	10	5	25	6	5	4	24	30	80	130
DDT 10%	60	55	5	5	10	3	2	2	4	8	13	46
Pyrocide 10%	60	87	77	98	91	75	35	50	117	158	170	232
Untreated	92	128	127	115	127	112	95	105	162	197	297	371

[1] Precipitation in inches during this period was as follows: August 6, .17; August 10, .20; August 15, T.; August 16, .58

DDT for Control of a Book Louse[1]

D. D. JENSEN and F. G. HOLDAWAY *University of Hawaii Agricultural Experiment Station, Honolulu*

The following information on the effect of DDT on a population of book lice tentatively identified by Mueller as *Liposcelis divinatorius* on rabbit hides, was obtained incidental to a study of the effect of DDT in protecting rabbit skins from attack by hide beetles (Jensen & Holdaway 1946, in press).

The rabbits were killed February 1, 1945 at Honolulu. Before being dried, the fresh hides were treated with DDT dusts and sprays at the concentrations given in table 1. Three hides were used in each treatment, and, after drying, the hides were wrapped in medium-weight wrapping paper. Each package was placed in a separate glass jar, the open end of which was covered with white cloth. The cages were prepared to limit hide beetle movement but apparently did not prevent the entry of book lice. The hides were examined 21 days after treatment and again 41 days after treatment. During these examinations no book lice were found on any hides. Examination of the hides 170 days after treatment revealed that an infestation of book lice had developed on some of the hides. In each treatment counts were made of the lice present on one-half of the outside surface of a single hide (turned inside out). The lice were collected with an aspirator and transferred to alcohol for counting. Eggs as well as nymphs and adults were obtained, but only nymphs and adults were considered in the infestation counts. The book lice were found to be most abundant in the crevices and folds of the skin.

Table 1.—Effect of DDT treatment on the population of book lice on rabbit hides.

TREATMENT	LIVING NYMPHS AND ADULTS ON ONE-HALF OF OUTSIDE OF ONE HIDE 170 DAYS AFTER TREATMENT[3]
1% DDT dust[1]	297
3% DDT dust	158
5% DDT dust	53
10% DDT dust	9
1% DDT spray[2]	20
3% DDT spray	0
5% DDT spray	0

[1] *Gesarol A 20* (Geigy Co.) diluted with pyrophyllite.
[2] Technical DDT (Pennsylvania Salt Co.) in kerosene.
[3] Comparable counts could not be made on the check hides as the skins had been nearly destroyed by hide beetles.

The untreated check hides had been destroyed so completely by hide beetle larvae that only fur and an occasional small patch of skin remained. The number of lice recorded for the check hides is, therefore, no indication of the potential population of book lice on an untreated hide undamaged by hide beetles. As a result, no evaluation can be made of the effectiveness of the least effective treatment (1 per cent DDT dust) as compared with no treatment.

Table 1 presents the population counts for the respective DDT treatments. The results show clearly that a 1-per cent dust permitted development of a high population of lice. A consistent decrease in the number of lice on hides resulted from treatment with dusts of increased concentration. However, a 10-per cent dust was not much more effective than a 1-per cent spray in preventing population increase. At the same time, sprays of 3 and 5 per cent DDT provided complete protection against the establishment of book lice on rabbit hides in this experiment. Since the book lice did not become established on any hides until at least 41 days after treatment, it is considered improbable that the kerosene itself was responsible for protecting the sprayed hides from book lice. Evaporation of all kerosene had taken place before the first examination 21 days after treatment. Furthermore, the hides sprayed with 1 per cent DDT were not completely protected from book lice, although they received as much kerosene as did the hides on which no lice became established.—2-11-46.

[1] Published with the approval of the Director as Technical Paper No. 133 of the University of Hawaii Agricultural Experiment Station.

Hadrobregmus gibbicollis Infesting Woodwork

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Doane *et al.* (1936: 218) cite *Hadrobregmus gibbicollis* Lec. (Anobiidae) LeC. from weathered timbers of Douglas fir in the San Francisco Bay region, and illustrate the work of the species. Furniss (1938) records it similarly at Puyallup, Washington, and in British Columbia. Recently the author's attention was called to another injurious occurrence of the species in the Hoh River region of Jefferson County, on the Olympic Peninsula of Washington. The weathered spruce boards of the flooring of a porch had been thoroughly tunneled by the beetles and their larvae, although some of the resulting destruction may have been due to fungi.—1-21-46.

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An Early Use of Arsenic as an Insecticide

J. A. MUNRO, *North Dakota State College, Fargo*

An early reference to the use of arsenic as an insecticide is found in "Systema Agriculturae; The Mystery of Husbandry Discovered," by John Worlidge, 3rd Edition, page 223, London, 1681, in which the author outlines its use in ant control as follows:

> "Also you may make Boxes of Cards or Pasteboard pierced full of holes with a Bodkin, into which Boxes put the Powder of Arsenick mingled with a little Honey; hang these Boxes on the Tree, and they will certainly destroy them (the ants): make not the holes so large that a Bee may enter, lest it destroy them."

Interestingly enough, the method with slight modification is still used in combating ants.

JOURNAL OF ECONOMIC ENTOMOLOGY

Official Organ American Association of Economic Entomologists

Vol. 39 April, 1946 No. 2

The National Science Foundation

At its meetings in St. Louis, March 27–29, 1946, the North Central States Branch of the American Association of Economic Entomologists adopted the following resolution:

WHEREAS, The Kilgore-Magnuson Bill *S-1850* represents the nearest approach to the most desirable legislation for the development of a National Science Foundation.

THEREFORE, BE IT RESOLVED, That the North Central States Branch of the American Association of Economic Entomologists urges its members and all other entomologists to support the passage of this bill by letters and personal contacts with senators and representatives in the Congress.

WHEREAS as it appears probable that *S-1850* or a similar bill will be passed by Congress and

WHEREAS we as entomologists have a deep and sincere interest in the structure, functions and work of the Science Foundation which may be established,

THEREFORE, BE IT RESOLVED: We recommend to the President of the Parent Association the appointment of a committee to follow the progress of this legislation with specific instructions to acquaint the President of the United States and the administrative officers of the National Science Foundation, when and if appointed, with the importance of entomology in War and Peace and the desirability of the appointment of entomologists to membership on the scientific committees of the several divisions; with particular emphasis on the Divisions of biological sciences, health and medical sciences and national defense.

BE IT FURTHER RESOLVED, That we urge the committee, the national officers and the executive committee of the Parent Association to study, determine and adopt suitable measures or means of assuring adequate financial support for the committee.

President Clay Lyle acted promptly upon this resolution. In his letter of April 9 he requested C. J. Drake, E. F. Phillips, and F. L. Campbell to "serve as the committee specified and for the purposes indicated, with Dr. Campbell as Chairman." These three men accepted the assignment.

I shall assume that the majority of the membership of the parent Association and of all its Branches favor the passage of *S-1850* and therefore are in agreement with the first two paragraphs of the above resolution. In the event that this bill becomes law without undesirable amendments I am certain that all entomologists will support the fifth paragraph of the resolution. However, the Committee cannot attempt to carry out its specific instructions until the bill is passed. Because the Committee was instructed indirectly to make only individual efforts "to support the passage of this bill . . . ," I consulted President Lyle, who replied in his letter of April 30: "I think it would be very appropriate for you as chairman of the committee to urge entomologists to contact their senators in the most effective way to secure the passage of Senate Bill 1850." Therefore I am writing this editorial on May 4 and will send copies of it to key entomologists in advance of publication.

It is gratifying to find that organized entomologists are taking more and more interest in the relation of entomology to other sciences and in the position of importance that entomology should occupy in science as a whole. This trend is indicated by increasing membership of entomologists in the American Association for the Advancement of Science, by their desire to play a significant part in the

activities of Section F of that Association, by their appropriation of a substantial sum for the building fund of the A.A.A.S., and finally by their support of *S-1850* and their desire to have entomology properly represented on the committees of certain divisions of the proposed National Science Foundation.

Entomologists who are members of the A.A.A.S. and who read the publications of that Association are well informed about the progress of science legislation in Congress. Dr. H. A. Meyerhoff, Executive Secretary of the A.A.A.S., has done and is doing splendid work both in an advisory capacity on science legislation and as a reporter to scientists (through the pages of *Science* and the *A.A.A.S. Bulletin*) of current developments in such legislation. I am indebted to him for my facts on *S-1850*.

Those who have not yet read the full text of this bill can find it in the February 22 issue of *Science*. It has also been published in the March 25 issue of *Chemical and Engineering News*. *S-1850* was reported out of committee on March 19. According to Dr. Meyerhoff, it is in line for consideration soon. He fears, however, that it may lose its place to other bills that the Senate may consider more urgent and that it may not come up during the present session. If the Senate does pass it late in the session, the House may not have time to act on it. In either case the bill would have to be reintroduced at the next session of Congress. Much of the procedure would have to be repeated, and at best a year's delay in passage of the bill would be expected. Unless scientists make a concerted effort *now* to tell their senators that the bill is sound, important, and urgent, it will probably die in the Senate. Anyone who reads the newspapers can probably name several bills in addition to the annual appropriation measures that could keep the Senate busy until summer adjournment. And remember that this is an election year.

The present opinion of scientists on *S-1850* is indicated by returns on a ballot sent to all members of the A.A.A.S. Council. The question was whether President Conant should appoint a special committee to work for the passage of *S-1850*. Of 240 who had voted at the last count, 230, including your Councilors, voted yes.

I favor *S-1850* for entomology and for science in general. Some entomologists may be lukewarm about it because they do not believe it will help them. They are already receiving Federal or State appropriations and think it unlikely that the National Science Foundation would supplement their funds for the study of economic problems. They may be right, but they can be helped in other ways. Prior to the war fundamental research in insect taxonomy, morphology, ecology, physiology, biochemistry, and pathology received little financial support from any source. Toxicology was favored by considerable support from the insecticide industry, but many of the projects undertaken supplied bread and butter for graduate students rather than new knowledge of broad significance or utility. During the war the Committee on Medical Research and the Chemical Warfare Service lent their support to a number of truly fundamental projects. As a result insect physiology and toxicology boomed. If these and other branches of entomology are to grow vigorously and fertilize applied research, continuous and substantial support of university research in these subjects is needed. It can be anticipated only from the National Science Foundation.

A few scientists fear that the National Science Foundation may stifle freedom of research by political control. To be sure, it would be preferable for productive research men to be independently wealthy and spend their own money as they see fit, but few are so favored and the majority somehow must receive compensation for services rendered or anticipated. The designers of *S-1850* have been continuously aware of the necessity of safeguarding freedom of research and have made provisions in the bill to do so in so far as it could be done without sacrificing government responsibility for the expenditure of public funds. Certainly individual initiative in research can function as well under the National Science Foundation as it does under the Office of Experiment Stations. The Foundation will not supersede, curtail, or limit the functions or activities of the Office of Experiment Station, the Agricultural Research Administration, or of any other government agency authorized to engage in scientific research and development.

The Foundation offers not only the hope of obtaining greater support for fundamental research in entomology, but by granting scholarships and fellowships the Foundation may also attract the kind of students who will be a credit to the profession. Through the Foundation better facilities for publication of entomological research may be made available.

The third paragraph of the entomologist's resolution takes too much for granted. Congress will pass *S-1850* or a similar bill at this session only if large numbers of scientists become thoroughly aroused about it and transmit their enthusiasm to Congress. What bill, if any, might be passed by the next Congress is unpredictable. By that time the iron will have grown cold. Therefore, in the words of Dr. Meyerhoff, "This is the time for action. If you favor *S-1850*, telegraph or write to your senator now!"

F. L. CAMPBELL

FIFTH ANNUAL MEETING OF THE NORTHWEST VEGETABLE INSECT CONTROL CONFERENCE

The fifth annual meeting of the Northwest Vegetable Insect Control Conference was held in Portland, Oregon on January 21 and 22, 1946. Entomologists from the Northwest states of Idaho, Oregon, Montana, Utah, and Washington were in attendance. As in previous conferences new developments in the control of the principal vegetable insect pests in the Northwest were discussed informally. Discussion was directed toward the following subjects:

DDT—Applications and Limitations, H. E. Morrison, discussion leader

New Insecticides Other Than DDT, E. P. Breakey, discussion leader

Insect Pests New to the Region, C. F. Doucette, discussion leader

Reports on Standing Projects on Vegetable Insect Control, J. C. Chamberlin, discussion leader.

Miscellaneous—New Methods and Techniques, Aircraft Crop Dusting, Plant Tolerance or Resistance to Insect Attack, H. C. Manis, discussion leader.

Review of Insecticide Situation, A. J. Flebut, discussion leader.

The executive committee in charge of arrangements for the 1946 meeting were: Don C. Mote, Oregon State College, Corvallis, *Chairman;* E. P. Breakey, Washington State College, Sumner, *Co-Chairman;* and T. A. Brindley, U. S. Department of Agriculture, Moscow, Idaho, *Secretary.*

The following executive committee was elected for the coming year: R. L. Webster, Washington State College, Pullman, *Chairman;* B. J. Landis, U. S. Department of Agriculture, Union Gap, Washington, *Co-Chairman;* and T. A. Brindley, U. S. Department of Agriculture, Moscow, Idano, *Secretary.*

The following members attended the conference:

D. H. Brannon	Pullman, Washington
E. P. Breakey	Puyallup, Washington
T. A. Brindley	Moscow, Idaho
J. A. Callenbach	Bozeman, Montana
E. C. Carlson	Mt. Vernon, Washington
J. C. Chamberlin	Forest Grove, Oregon
D. J. Crowley	Long Beach, Washington
C. F. Doucette	Sumner, Washington
J. R. Douglass	Twin Falls, Idaho
P. M. Eide	Pullman, Washington
H. C. Hallock	Twin Falls, Idaho
F. G. Hinman	Moscow, Idaho
B. J. Landis	Union Gap, Washington
M. C. Lane	Walla Walla, Washington
H. C. Manis	Moscow, Idaho
C. H. Martin	Corvallis, Oregon
H. E. Morrison	Corvallis, Oregon
D. C. Mote	Corvallis, Oregon
H. S. Scullen	Corvallis, Oregon
W. E. Peay	Logan, Utah
W. E. Shull	Moscow, Idaho
L. L. Stitt	Puyallup, Washington
B. G. Thompson	Corvallis, Oregon
R. L. Webster	Pullman, Washington

In addition to these, representatives of 31 industrial organizations attended. The total attendance was 90.

TOM A. BRINDLEY, *Secretary*

PROCEEDINGS OF THE SEVENTEENTH ANNUAL MEETING

EASTERN BRANCH, AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS,

Hotel New Yorker, November 29 and 30, 1945

The Seventeenth Annual Meeting of the Eastern Branch, American Association of Economic Entomologists, was called to order by the Chairman, Hugh Glasgow, at 10:00 A.M., November 29, 1945, in the North Ballroom of the Hotel New Yorker in New York City. Doctor Glasgow, assisted by Dr. H. F. Dietz, Vice-Chairman, presided over the two-day meeting which was devoted to the reading and discussion of 43 papers. At the finish of the paper reading session a round table discussion of "Limitations of DDT as an Insecticide" was held on the afternoon of the second day.

At the end of the morning session of November 29, the Chairman, Hugh Glasgow, appointed the following committees:

Nominations: R. B. Friend, W. E. Blauvelt, L. P. Ditman

Auditing: H. B. Weiss, B. B. Pepper

Resolutions: W. J. Schoene, S. W. Bromley, A. B. Buchholz

Awards: F. H. Lathrop, W. E. Fleming, R. B. Arnold

The Secretary-Treasurer made the following report, which was referred to the Auditing Committee.

REPORT OF THE SECRETARY-TREASURER

The Executive Committee waived the dues of members for the year 1944–45 due to the fact that no regular meeting was held in 1944 and an ample surplus was on hand in the Treasury. Notices of the meeting were sent to some 600 members of the American Association of Economic Entomologists with addresses listed in the JOURNAL as residing in the eastern territory. Indications are that membership dues for 1945–46 will nearly double the average for the past five years.

The sixth or 1943 annual award was made to F. H. Lathrop and C. O. Dirks, for their paper, "Timing the Seasonal Cycle of Insects," published in the April 1944 issue of the JOURNAL.

FINANCIAL STATEMENT

Balance on hand, November 10, 1943			$2,099.97
Receipts			
Dues for 1943		$ 192.00	
Dues for 1945 to November 28, 1945		159.00	
Receipts from Entoma			
1944	$ 474.34		
1945	5,000.00	5,474.34	
Total Receipts		$5,825.34	7,925.31
Disbursements			
Bellevue Hotel, Services 1943 meeting		147.00	
Payment to Secretary-Treasurer			
1943		200.00	
1944		200.00	
1945		200.00	
Clerical Services			
Eastern Branch		64.48	
Entoma		270.05	
Postage			
Eastern Branch		72.60	
Entoma		563.25	
Printing			
Entoma		3,703.79	
Programs, 1945 meeting		32.77	
Expenses, Secretary-Treasurer		11.75	
Travel and supplies, Entoma Committee		61.49	
Awards, 1943		75.00	
Engraving		2.00	
Returned check of Littig (Stale Date)		2.00	
Total Disbursements		$5,609.22	
Balance on hand, November 28, 1945			$2,316.09
Distributed as follows:			
Checking Account, The Union National Bank and Trust Company, Mount Holly, N. J.			$2,314.09
Cash on hand			2.00
			$2,316.09

BYRLEY F. DRIGGERS
Secretary-Treasurer

REPORT OF EDITORIAL COMMITTEE OF *Entoma*

Doctor George S. Langford, Editor of *Entoma*, reported that the Sixth Edition of *Entoma* had been issued and that most of the copies were in the mail or had been sent out to members. He stated that after considerable discussion the Editorial Committee decided to have 5,000 copies of *Entoma* printed. Approximately 2,500 of these were required for immediate use in mailing out to members of the Eastern Branch and of the American Association of Economic Entomologists as well as the advertisers. Approximately 500 should be retained for used when the next edition of *Entoma* is to be prepared. Dr. Langford thought there would be no difficulty in disposing of the remainder to Plant Pathologists, County Agricultural Agents and others.

Dr. Langford stated that the delay in getting the 6th edition printed was partly due to paper shortage, labor difficulties at the printer and the extra amount of work involved in getting out the larger size and bigger edition. Interest in *Entoma* is indicated by the fact that paid advertisements and listings were about 75 per cent greater for the 6th edition than for the 5th edition. Dr. Langford expressed his appreciation to all the members of the Editorial Committee and to others who assisted in supplying information for the 6th edition. A summary of the financial statement as presented by Dr. Langford follows.

SUMMARY

BUSINESS ACTIVITIES—6TH EDITION OF *Entoma*

Sales			
Advertising—			
1945 Edition (paid)	$4,855.59		
1945 Edition (unpaid)	295.00	$5,150.59	
Paid listings—1945 Edition		279.00	
Sales 1945 Edition (November 24)		227.80	
Sales 1943 Edition		147.59	
Gross business as of November 24, 1945			$5,804.98

Expenses			
1. Stationery, envelopes, circulars, etc.		$ 175.75	
2. Printing *Entoma*		3,641.29	
3. Clerical help and Notary fees		255.60	
4. Freight bills (35¢ unpaid)		8.38	
5. Stamps		445.00	
6. Telephone bills (not paid)		6.72	
Total expenses			$4,532.74
Net profit as of November 24			$1,272.24
Estimated Earnings for 1945 Edition			
1. Assets (estimated)			
a. Present net profit	$1,272.24		
b. Sales—2,000 copies	2,000.00		$3,272.24
2. Liabilities (estimated)			
a. Advertising for sale of 2,000 copies	$ 150.00		
b. Stamps for mailing	300.00		
c. Clerical help	200.00		
d. Miscellaneous	122.24		
Estimated net earnings		$ 772.24	$2,500.00
Status of Funds Received			
1. Total funds received		$5,509.98	
2. Distribution of funds			
a. Transferred to Eastern Branch	$5,000.00		
b. On deposit—Prince Georges Bank and Trust Company	509.98		
		$5,509.98	

REPORT OF COMMITTEE TO CONSIDER COMPENSATING EDITOR OF *Entoma*

Professor C. C. Hamilton, Chairman, and H. F. Dietz and C. H. Hadley reported that this Committee recommends that the Editor of *Entoma* be paid a sum of $500.00 for his services for getting out the 6th edition of *Entoma* and for each succeeding year that a new edition is printed. This was moved, seconded and unanimously approved by the membership.

The report of the Secretary-Treasurer and the following committee reports were all adopted by the Branch and new officers were elected for 1946.

REPORT OF COMMITTEE ON RESOLUTIONS

Your Committee desires to present the following resolutions:

(1) Inasmuch as no inconsiderable part of the success of the 17th Annual Meeting has been due to the Committee on local arrangements and to Dr. Driggers in particular,

Be it resolved, that the Eastern Branch of the American Association of Economic Entomologists proffer their thanks to this Committee for its able work.

(2) Inasmuch as the Management of the Hotel New Yorker has amply provided facilities necessary to the success of our meeting,

Be it resolved, that the thanks of our organization be expressed to this management.

(3) Inasmuch as a Listing Agency of Entomologists returning from the Armed Forces and War Services—so needed by both those seeking and those offering Entomological employment—is being established by the parent association through the good offices of the Secretary, Dr. Ernest N. Cory,

Be it resolved, that the thanks of our organization be expressed to Dr. Cory for this commendable and necessary venture.

(4) Inasmuch as since our last meeting one of our outstanding members and officers, who with Drs. Headlee, Britton, Weiss and Burgess, was one of the founders of what later became known as the Eastern Branch, Dr. E. Porter Felt has passed away,

And inasmuch as since our last meeting, our duly-elected Secretary-Treasurer, Mr. Charles S. Beckwith passed away while in office,

Be it resolved that the Secretary be instructed to write a letter of sympathy and appreciation of what these two members have done for our society, which should be sent to their respective families.

S. W. BROMLEY
A. B. BUCHHOLZ
W. J. SCHOENE, *Chairman*

Nov. 29, 1945

The Auditing Committee has examined the accounts of the Secretary-Treasurer and has found them to be correct and in good order.

HARRY B. WEISS
BAILEY B. PEPPER

REPORT OF NOMINATING COMMITTEE

Your Committee proposes the following persons to serve as officers of the Eastern Branch of the American Association of Economic Entomologists for the coming year.

For Chairman: HARRY F. DIETZ
For Vice-Chairman: J. O. PEPPER
W. E. BLAUVELT
L. P. DITMAN
R. B. FRIEND, *Chairman*

Under Miscellaneous Business, Mr. F. C. Nelson made a short statement relative to the purpose and aims of the Thomas J. Headlee Fellowship Fund.

Approximately 300 attended the meetings and the attendance and interest were excellent.

The following members and guests registered during the sessions.

Adams, E. W.
Adams, J. Alfred
Adams, J. F.
Alexander, C. C.
Anderson, Lauren D.
Arnold, R. B.
Avens, A. W.
Back, E. A.
Badertscher, A. Edison
Bailey, H. L.
Barnes, R. C.
Bashour, J. T.
Bayles, J. W.
Beard, R. L.
Becker, Geo. G.
Beinhart, E. G.
Bellwin, Zelda
Berg, Morris
Bickley, W. E.
Birnbaum, Morris
Billings, Samuel C.
Blasberg, C. H.
Boyd, William
Brann, J. L.
Bromley, S. W.
Buchholz, A. B.
Buettner, Wm.
Burgess, Emory D.
Bushland, R. C., Capt.
Chapman, Paul J.
Clark, S. W.
Collins, Donald L.
Compton, C. C.
Connola, Donald P.
Coon, B. F.
Cooper, James F.
Cowan, E. K.
Cox, James A.
Craig, F. Waldo
Crissman, W. I.
Cronin, Timothy C.
Dean, R. W.
Denny, F. E.
Dewey, J. E.
Dickenson, Barton
Dieter, C. E.
Dietz, H. F.
Dirks, Chas. O.
Ditman, L. P.
Driggers, B. F.
Eastman, P. M.
Eavis, H. J.
Evans, J. A.
Fall, B. B.
Farley, Arthur J.
Farmer, H. S.
Fenton, Alfred
Feustel, W. K.
Filmer, R. S.
Fleming, W. E.
Fletcher, J. H.
Foley, D. M.
Fox, H.
Franklin, D. M.
French, G. T.
Friend, R. B.
Froelicher, V.
Gambrell, F. L.
Gaul, A. T.
Gemmell, Louis G.

Ginsburg, J. M.
Girth, Harold
Glasgow, Hugh
Glasgow, R. D.
Glass, E. H.
Goble, G. J.
Goodhue, L. D.
Granett, Philip
Grayson, J. M.
Greenwood, D. E.
Griffiths, A. E.
Guy, H. G.
Gyrisko, G. G.
Hadley, C. H.
Hagmann, L. E.
Hamilton, C. C.
Hamilton, D. W.
Hammer, O. H.
Hansens, Elton J.
Haring, R. C.
Harman, S. W.
Harned, R. W.
Harris, C. S.
Hawkins, John H.
Heal, Ralph E.
Hervey, Geo.
Hetrick, L. A.
Heuberger, J. W.
Hitchner, L. S.
Hoeffler, J. H.
Horsfall, J. L.
Hough, W. S.
Hoyt, A. S.
Huckett, H. C.
Hutchins, F. E.
Jennings, Cedric C.
Johnson, Conrad C.
Johnson, J. P.
Joyce, R. F.
Karlovic, John
Karstens, Kenneth
Kerr, T. W.
Knutsen, M.
Laidlow, H. H.
La Plante, A. A.
Larson, N. P.
Lathrop, F. H.
Lee, Cecil S.
Leiby, R. W.
Leonard, M. D.
Lloyd, Poland J.
Logothetis, C.
Long, John C.
Luttan, I. H.
MacCreary, Donald
Maddrey, J. B.
Mail, George Allan
Marvin, Philip
Mason, A. C.
Maxwell, J. Myron
McGovran, E. R.
Medoff, John K.
Menusan, H.
Middleton, Wm.
Mikeska, L. A.
Miller, A. C.
Miller, J. V.
Moore, Warren
Morris, Ralph
Mulhern, T. D.
Nelson, F. C.
Norton, L. B.
Oakley, R. G.
Oatts, James D.
Payne, Nellie M.
Pepper, B. B.
Pepper, J. O.
Perrot, Max
Peterson, P. D.
Pierpont, R. L.
Poos, F. W.
Porter, B. A.
Pratt, H. B.
Pyenson, Louis
Reed, T. W.
Rex, E. G.
Roark, R. C.
Rosenthal, Max
Rowe, W. M.
Rudolfs, W.
Ruth, J. R.
Sanford, H. L.
Sankowsky, N. A.
Schmitt, J. B.
Schweitztebel, R. B.
Seiferle, E. J.
Setterstrom, C. N.
Shafer, J. I.
Shepard, Harold H.
Sherman, Martin
Sherman, R. W.
Singleton, J. M.
Smith, Chas. L.
Smith, Floyd F.
Smith, L. E.
Starr, Donald
Stearns, L. A.
Steiner, H. M.
Steinrock, Frank
Sutton, Robert
Swingle, M. C.
Synerholm, M. E.
Taschenberg, E. F.
Taylor, H. G.
Telford, H. S.
Thompson, B. T.
Thompson, F. M.
Thornton, N. C.
Tint, Howard
Torpin, P. D.
Townsend, James F.
Turner, Neely
Udine, E. J.
Underhill, G. W.
Vangeluwe, John
Walker, H. G.
Wallace, Philip
Wallace, R. T.
Ward, K. E.
Warren, Eleanor
Washburn, Richard H.
Watkins, T. C.
Wean, Robt. E.
Weed, A.
Weigel, Chas. A.
Weiss, H. B.
Wellman, R. H.
Wene, George
Westcott, Cynthia
Wheeler, E. H.
Whitlock, S. D.
Wilcoxon, Frank
Wilford, B. H.
Wilson, C. A., Capt.
Wood, H. J.
Woodbury, Chas. G.
Woodbury, E. N.
Woodside, A. M.
Zappe, M. P.

REVIEW

THE SKELETAL ANATOMY OF FLEAS, by Dr. R. E. Snodgrass. 89 pp, 21 plates. Smithsonian Miscellaneous Collections. Vol. 104, No. 18. April, 1946.

Because of the "Involvements in Research," applied entomology has become a mixture of chemistry, engineering, political science and sociology, with only an occasional disguised reference to such things as insects—or so it often seems to one who started out to be an entomologist because of his interest in insects.

But we are reminded from time to time that there is a science of entomology which deals with insects, their classification, their distribution, their habits and, fundamental to all insect problems, their structures. Dr. Snodgrass is surely one of the world's foremost exemplars of this phase of entomology. His latest publication is sufficiently well reviewed by its title for those who have long been familiar with the painstaking detail and thoroughness which Dr. Snodgrass' works are always characterized.

The skill and industry represented by these studies has never been more in evidence than in this latest of the many contributions made by this author. Economic entomology is to be congratulated on the fact that the group represented is one where exact knowledge of structures may well prove to have real practical importance and the growing realization of the importance of the group in the field of medical entomology makes the work most timely. Words can only feebly express our appreciation of this work but we can do no less than congratulate Dr. Snodgrass on another task well done and extend, so far as we may, the thanks of the profession to him.